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Sawaj

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(54) **IMAGE FORMING APPARATUS WITH ULTRASONIC VIBRATION GENERATOR**

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G03G 15/16 (2006.01)

(52) **U.S. Cl.**
USPC **399/319**

(58) **Field of Classification Search**
USPC 399/319
See application file for complete search history.

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(57) **ABSTRACT**

An image forming apparatus includes a first endless transfer belt, first extending members, a first transfer electric generator, a secondary transfer unit disposed outboard and at least partially facing the first endless transfer belt, and an ultrasonic vibration generator, including a vibration imparting part from which ultrasonic vibrations is applied to the first endless transfer belt. The secondary transfer unit and the first endless transfer belt form a transfer nip forming a transfer electric field due to a difference in electric potential therebetween. The first transfer electric field generator contacts the first endless transfer belt at a position other than a position disposed opposite the secondary transfer unit. The vibration imparting part contacts the first endless transfer belt at a position intermediate between the first transfer electric field generator and the secondary transfer unit in a direction of rotation of the first endless transfer belt.

11 Claims, 6 Drawing Sheets

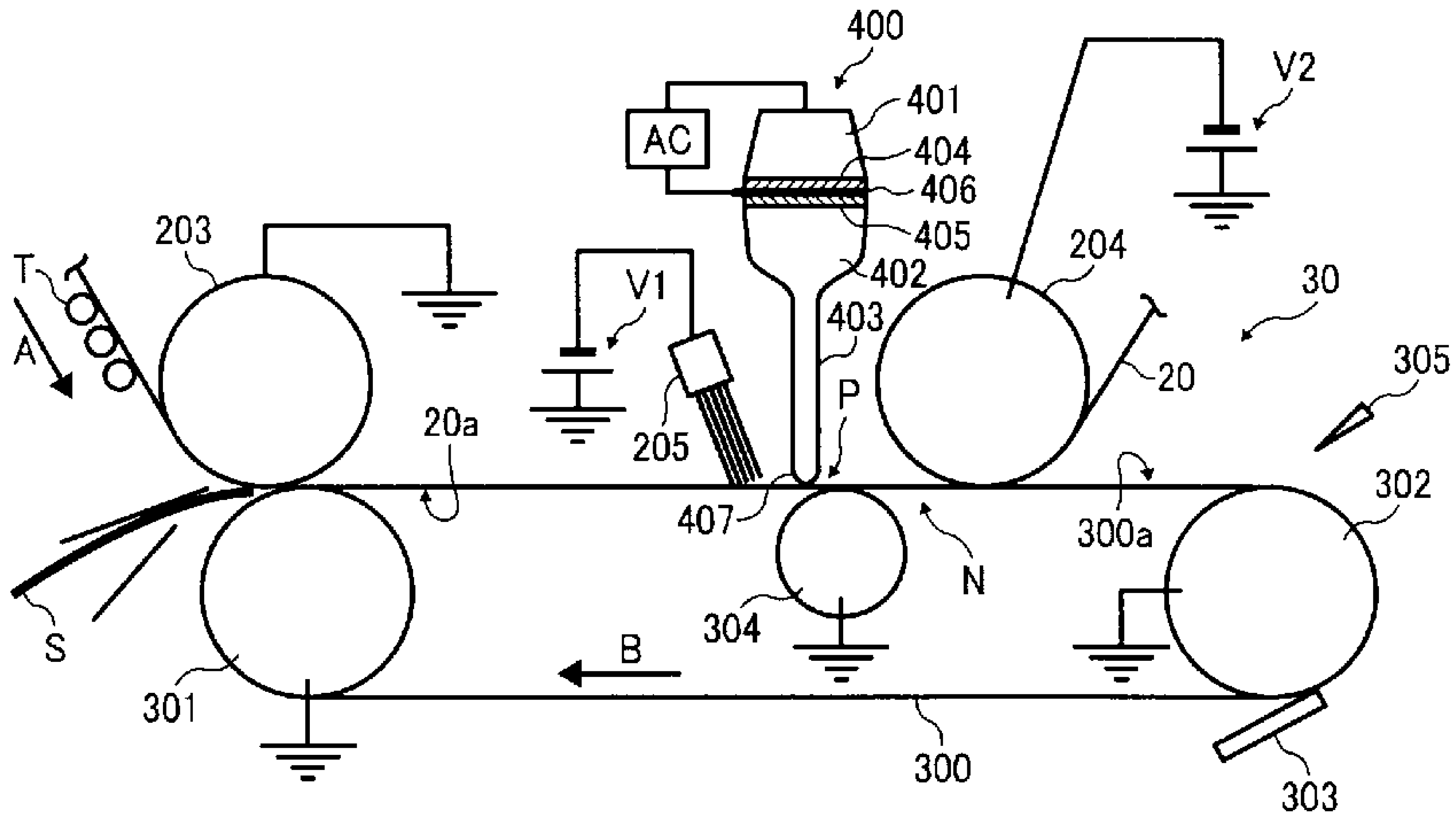

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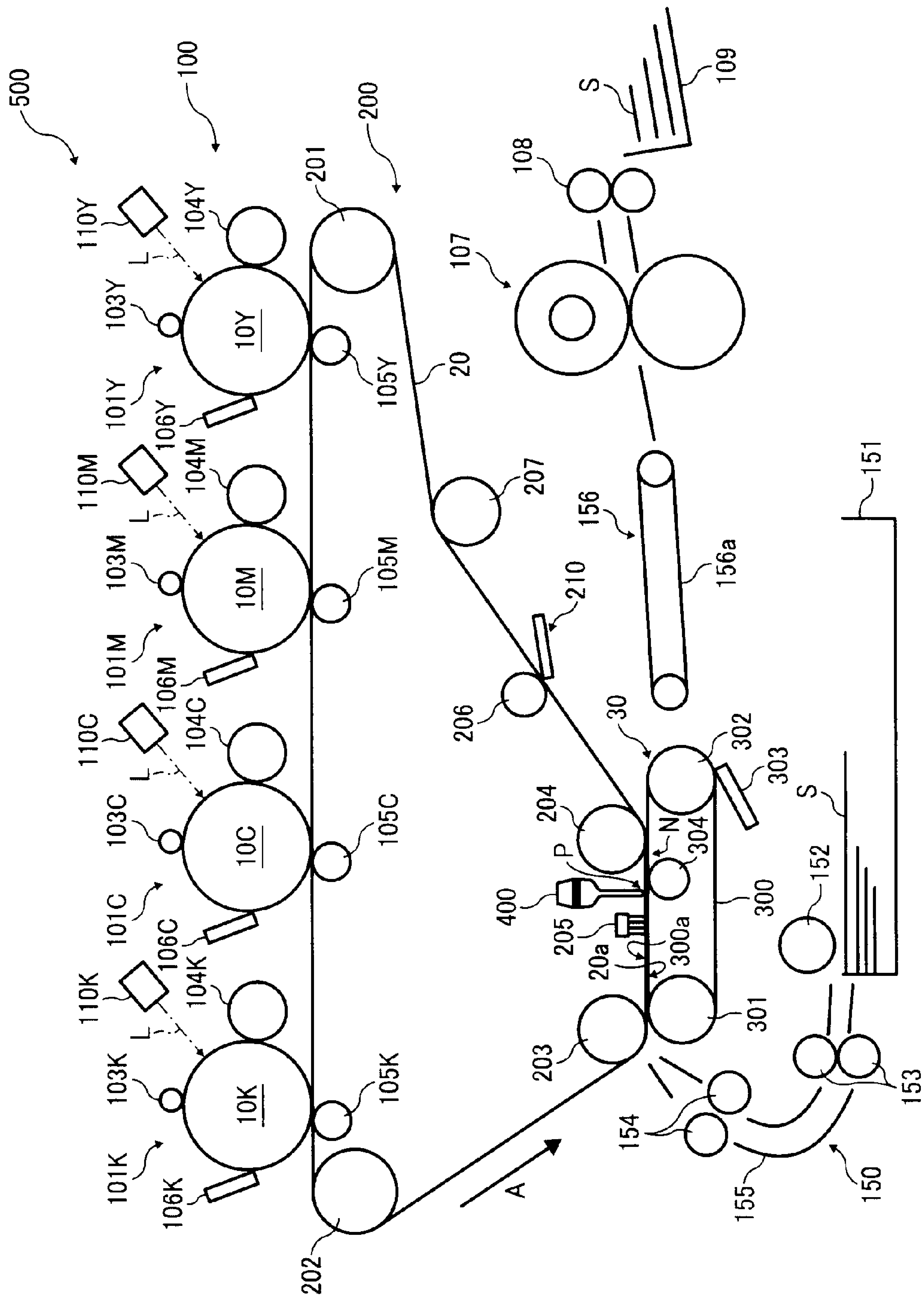
FIG. 1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200
110Y
103Y
104Y
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101Y
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105Y
201
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101M
106M
105M
207
110C
103C
104C
10C
101C
106C
105C
206
210
110K
103K
104K
10K
101K
106K
105K
L
202
203
204
205
20a
300a
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P
N
304
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107
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S
156
156a
151
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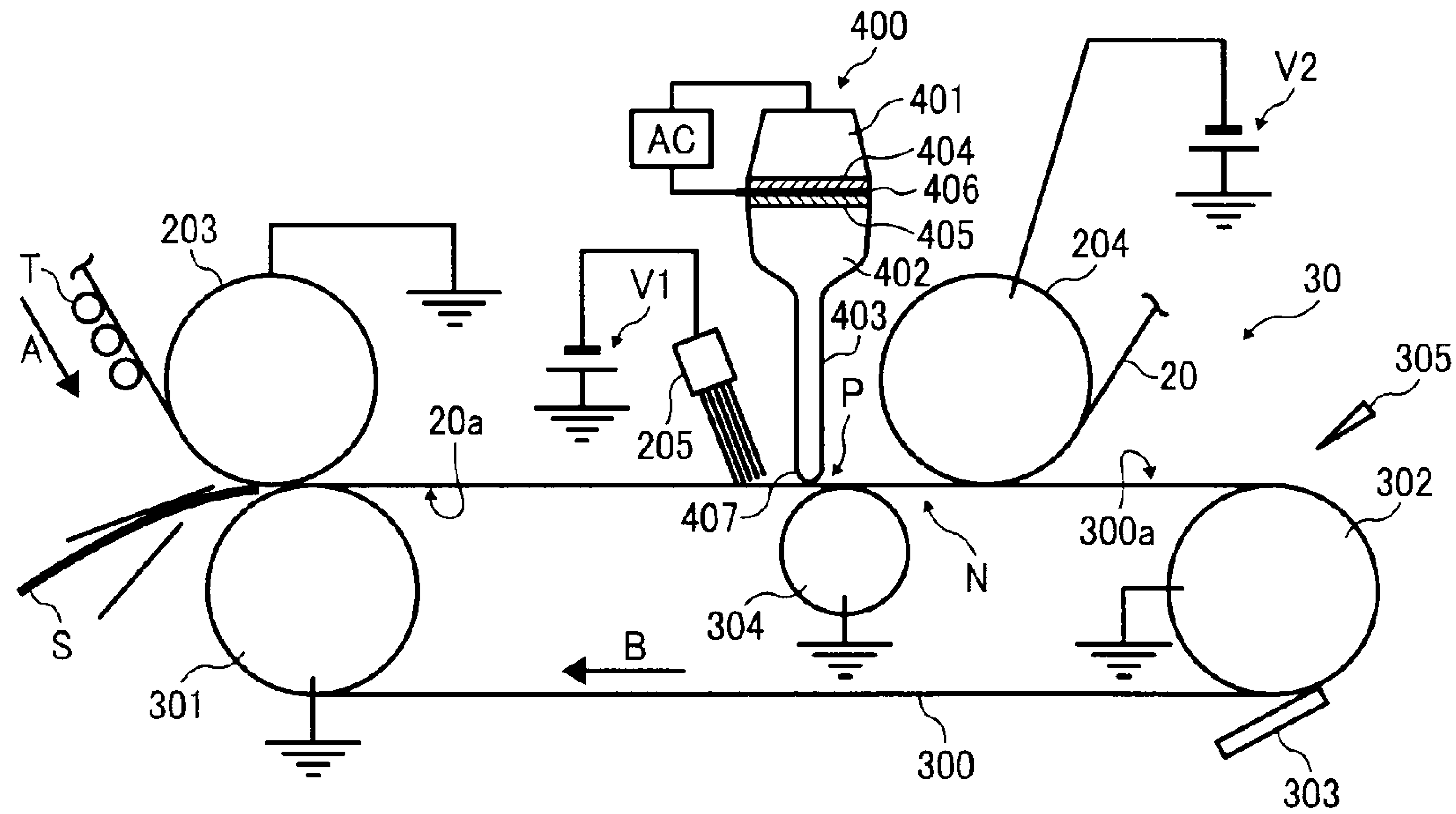
153
154
155
150

FIG. 2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V1
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S
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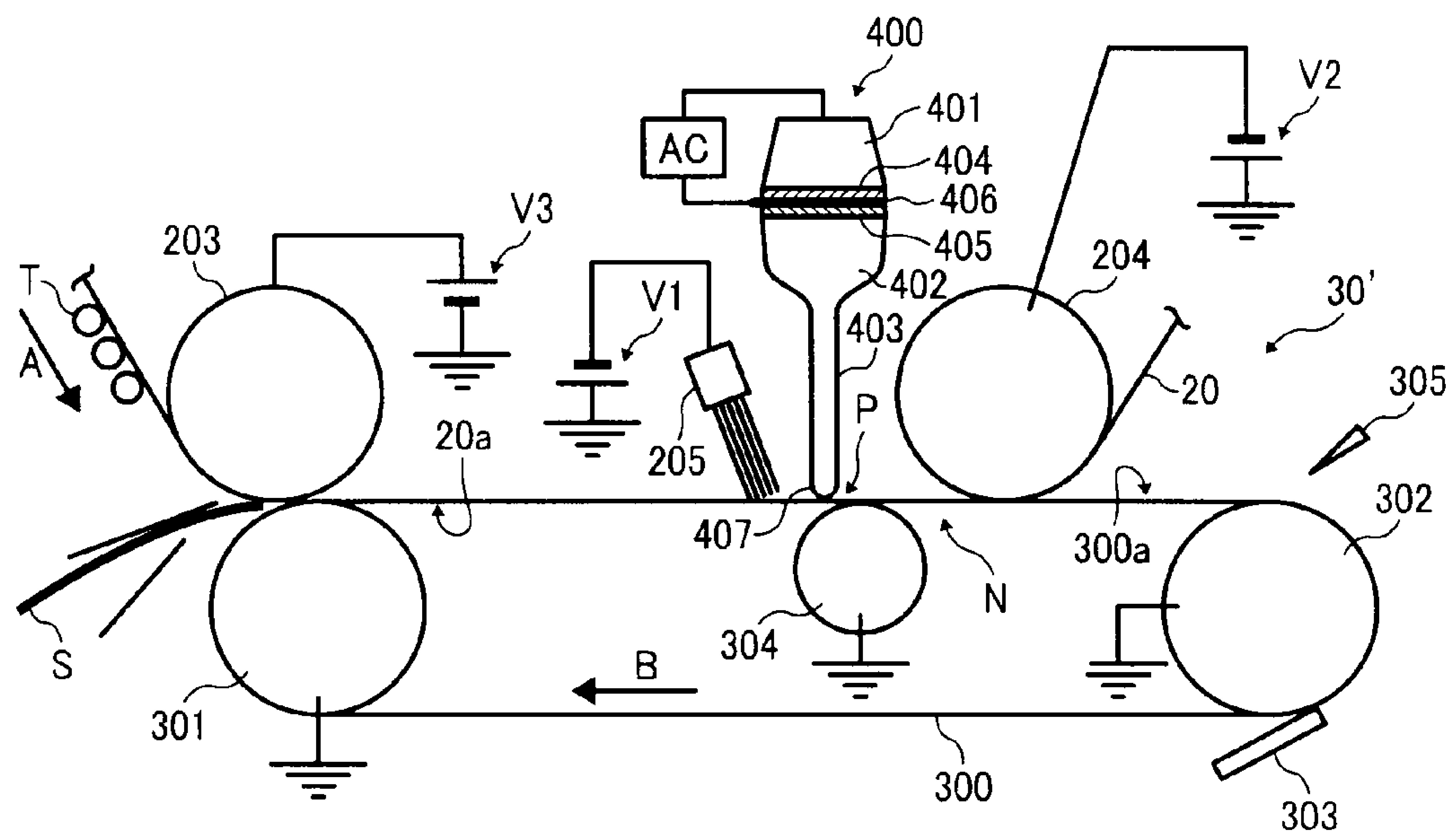
303

FIG. 3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T
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301
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303

FIG. 4

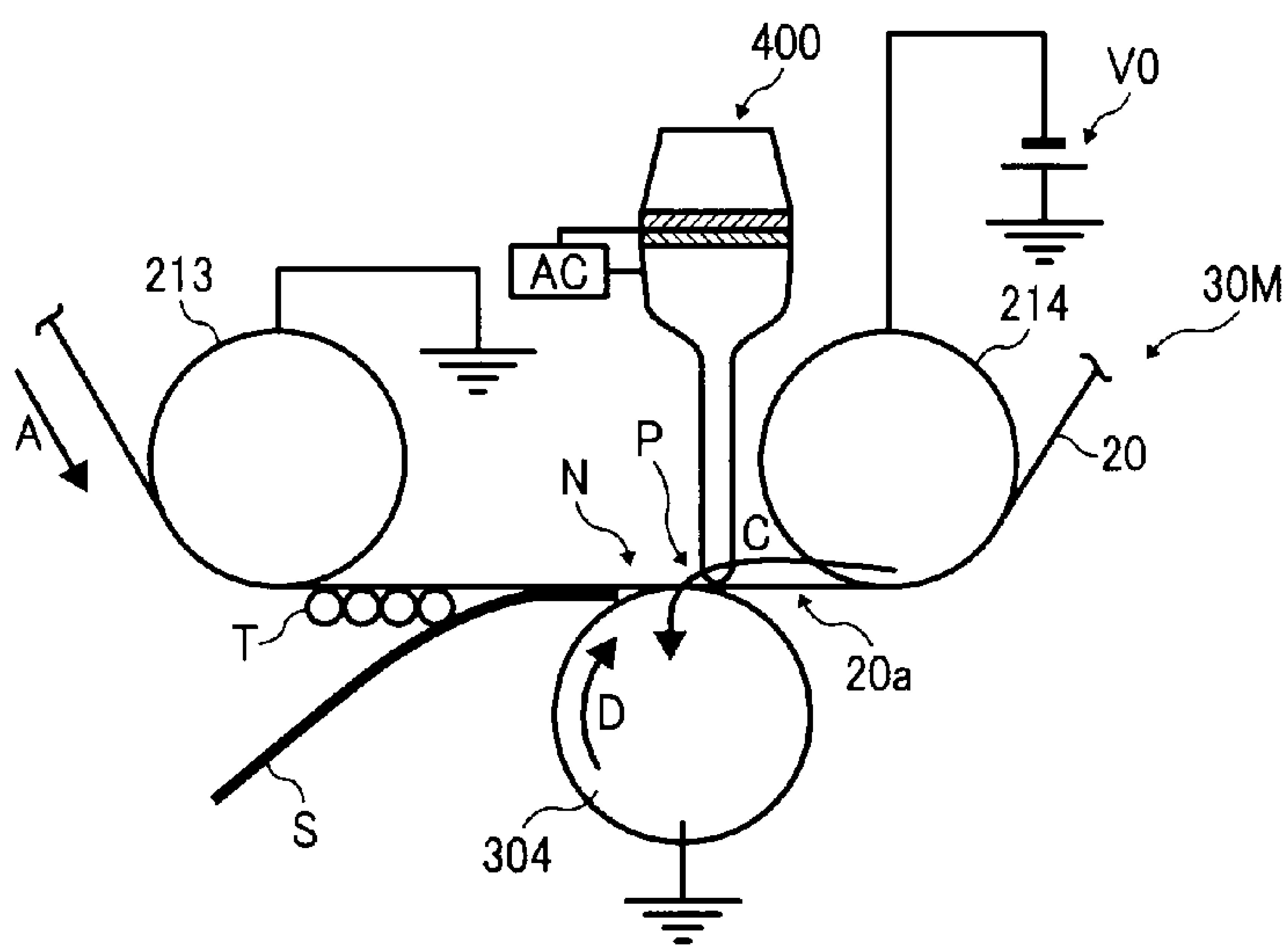
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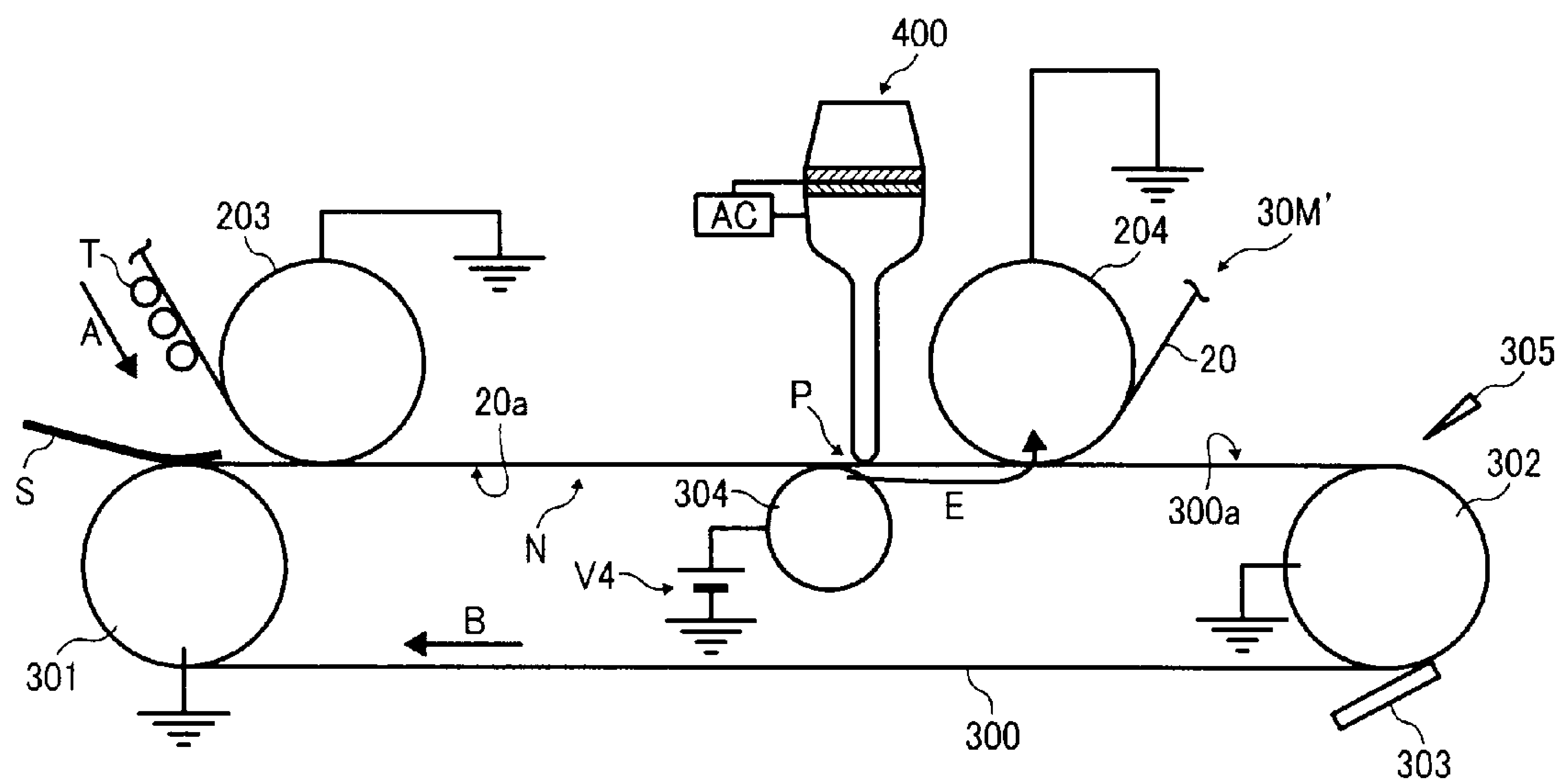
FIG. 5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301
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303

FIG. 6

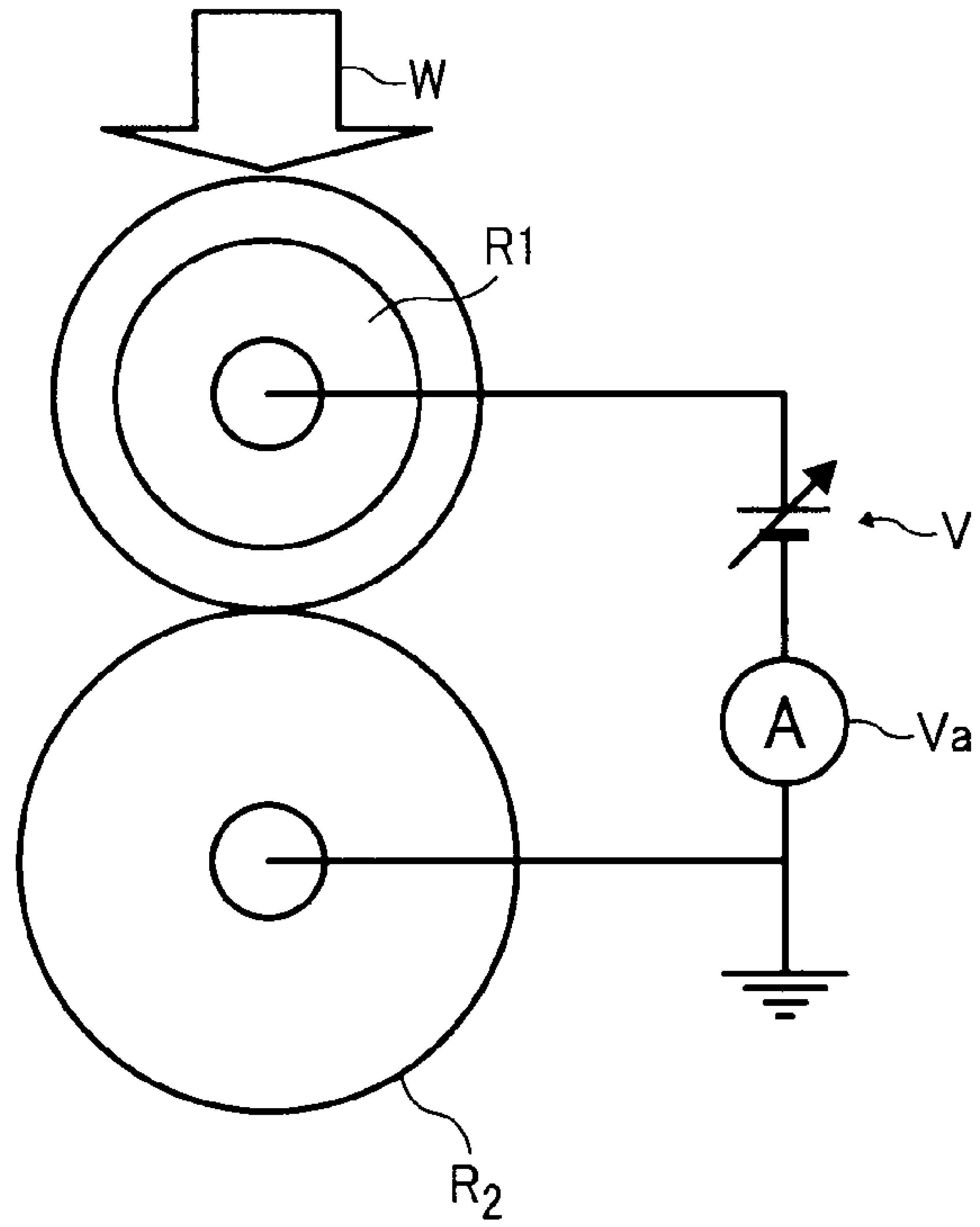


FIG. 7

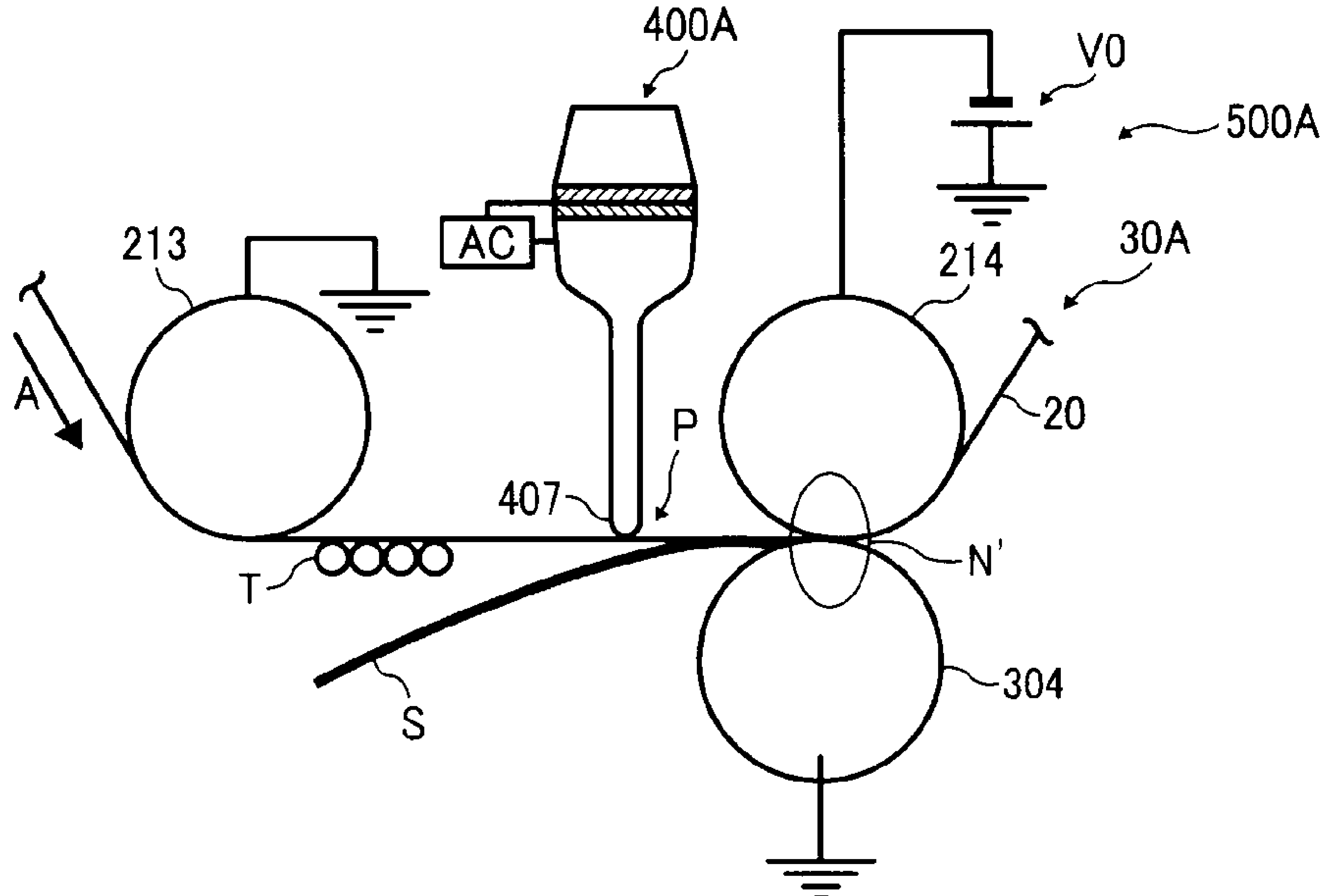
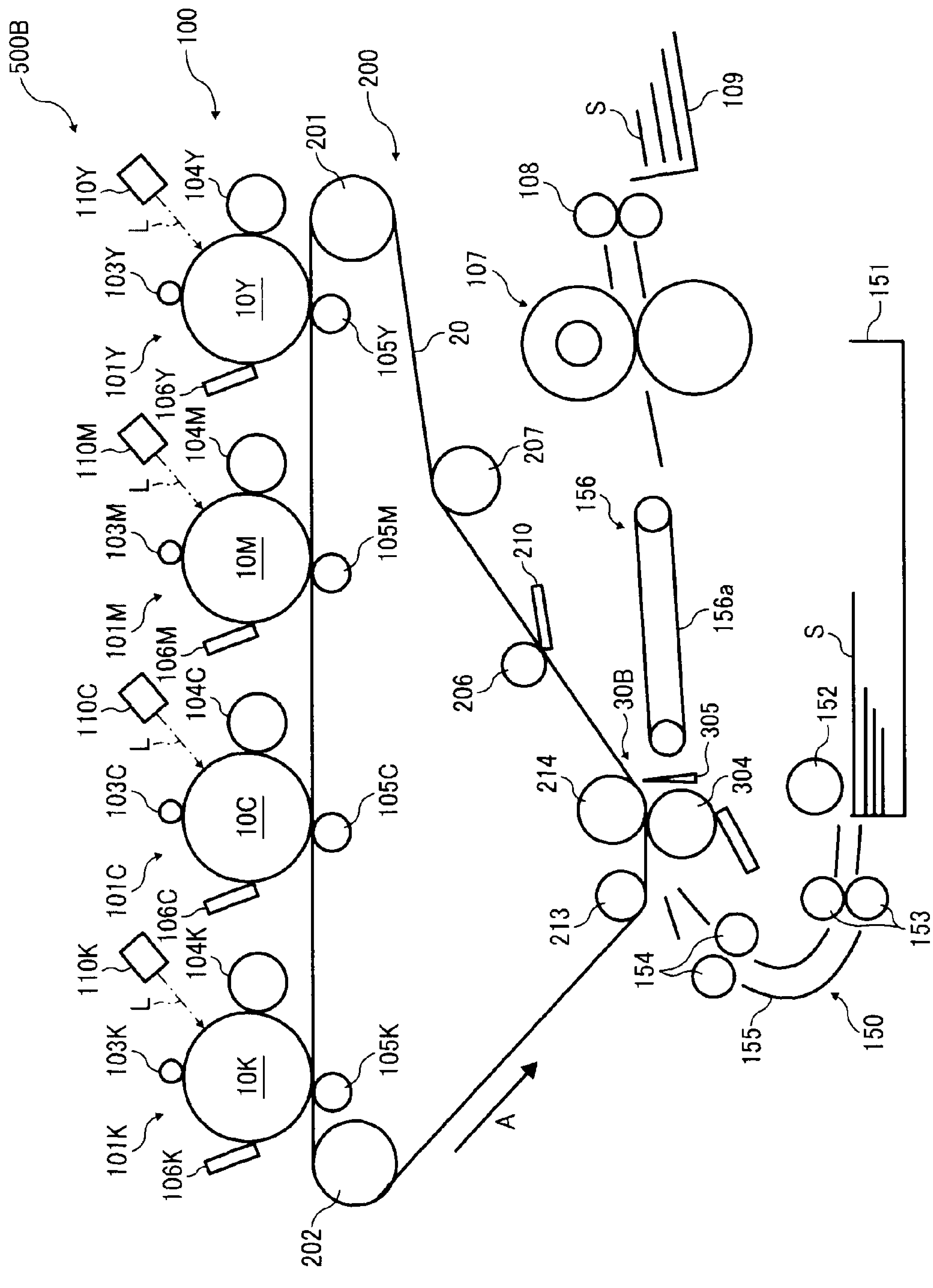


FIG. 8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10K
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104C
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105Y
105M
105C
105K
106Y
106M
106C
106K
110Y
110M
110C
110K
L
20
201
202
206
207
210
213
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30B
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A
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150
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153
154
155
156
156a

FIG. 9

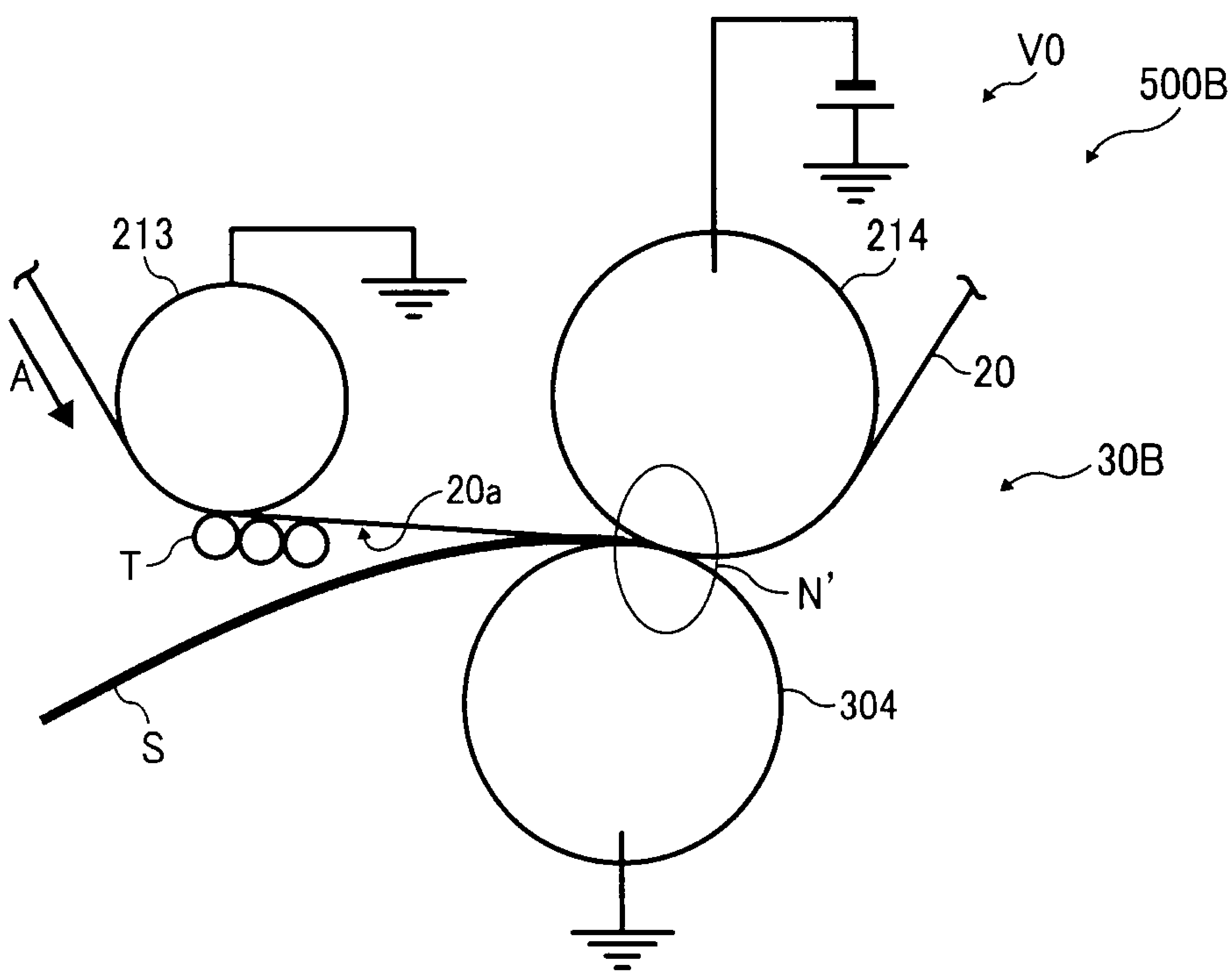

IMAGE FORMING APPARATUS WITH ULTRASONIC VIBRATION GENERATOR

CROSS-REFERENCE TO RELATED APPLICATIONS

The present invention claims priority pursuant to 35 U.S.C. §119 from Japanese Patent Application No. 2009-064463, filed on Mar. 17, 2009 in the Japan Patent Office, which is hereby incorporated by reference herein in its entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

Exemplary embodiments of the present invention relate to a copier, printer, facsimile machine, or similar image forming apparatus, and more particularly, to an image forming apparatus for transferring a toner image formed on a toner image carrying belt (e.g., an intermediate transfer belt) onto a sheet-like recording medium directly or via another toner image carrying member (e.g., a sheet conveyance member) to obtain a complete full-color image.

2. Discussion of the Related Art

In recent years, full-color image forming apparatuses for electrophotographic printing generally perform either a direct image transfer operation or an indirect image transfer operation. In the indirect transfer operation, respective single-color toner images formed on each image carrier that contacts an intermediate transfer belt are sequentially transferred onto the intermediate transfer belt by an electric field supplied by a transfer bias unit to form a composite toner image, in an operation that is referred to as primary transfer. Then, the composite toner image retained by the intermediate transfer belt is transferred onto a recording medium conveyed along the intermediate transfer belt, in an operation referred to as secondary transfer. Through the primary and secondary transfers, ultimately a full-color toner image is formed on the recording medium.

The image carrier used for the indirect transfer operation can be a drum-shaped photoconductor, a belt-shaped photoconductor, etc. By contrast, in the direct transfer operation, respective single-color toner images formed on each image carrier can be transferred onto a recording medium directly.

In an effort to further improve image quality, various techniques have been proposed to enhance toner image transferability.

One approach, for example, discloses an ultrasonic vibration generator that generates and applies ultrasonic vibrations to a transfer position of the toner image from a toner image carrying belt or an intermediate transfer belt onto a recording medium. This approach proposes a configuration that includes a corona generating unit disposed facing a surface of the toner image carrying belt extended between two extension rollers. In this configuration, a toner image is transferred onto the recording medium when the recording medium passes between the corona generating unit and the extended surface portion of the toner image carrying belt. The ultrasonic vibration generator includes a vibration imparting part that contacts an inner side of the extended surface portion of the toner image carrying belt.

This configuration further employs a non-contact transfer system. However, such a configuration uses an electrostatic force to closely contact the toner image carrying belt and a recording medium, is susceptible to poor transferability due to insufficient contact.

Another approach discloses a transfer roller and an ultrasonic vibration generator having a vibration imparting part. The transfer roller is charged with a transfer bias having a polarity opposite that of toner, and is disposed facing one of a set of an extension rollers extending the toner image carrying belt, with the toner image carrying belt interposed between the rollers. The vibration imparting part of the ultrasonic vibration generator is disposed facing the extension roller that contacts the transfer roller via the toner image carrying belt. More particularly, the extension roller set contacting the transfer roller via the toner image carrying belt includes multiple individual rollers arranged along its axial direction. The vibration imparting members contact the inner surface of the toner image carrying belt between the multiple rollers of the extension roller set.

In the configuration according to this approach, the transfer roller is pressed against one of the multiple rollers of the extension roller set via the toner image carrying belt to form a transfer nip. As a recording medium passes through the transfer nip, stable close contact between the recording medium and the toner image carrying belt can be achieved, resulting in a stable transfer process.

In this configuration, however, multiple narrow-width rollers are arranged along an axial direction of the secondary transfer roller. Consequently, the pressure exerted by each of the rollers on the belt differs depending on whether or not the roller contacts the toner image carrying belt along the axial direction of the transfer nip, which tends to cause uneven transfer and wrinkle the recording medium as the recording medium passes therethrough. Further, it is difficult for the toner image carrying belt to vibrate easily at the transfer nip where the two rollers meet and contact each other. The upshot is that toner image transferability cannot be enhanced by applying an ultrasonic vibration to such a configuration.

It is possible to have an arrangement in which the image forming apparatus includes an ultrasonic vibration generator for applying an ultrasonic vibration to a toner image carrying belt at a different position from where the two rollers contact each other as described above. In such a configuration, a transfer-roller opposed roller and a secondary transfer roller are used. The transfer-roller opposed roller serves as an extension roller to which a transfer bias having the same polarity as that of the toner, is applied from a transfer power source. Together, the transfer-roller opposite roller and the secondary transfer roller form a contact area, which is also referred to as a secondary image transfer nip. In the secondary image transfer nip, a toner image formed on the intermediate transfer belt is transferred onto a transfer sheet serving as a recording medium. Of note is that the ultrasonic vibration generating unit includes a vibration imparting part disposed to contact the inner side of the extended surface portion of the intermediate transfer belt in an area that is located in between adjacent intermediate transfer belt rollers.

However, even this configuration was found not to improve image transferability significantly compared to a configuration without the ultrasonic vibration generator. Nor was image transferability improved when the target object onto which the toner image is transmitted is not the recording medium but another toner image carrying belt.

SUMMARY OF THE INVENTION

Exemplary aspects of the present invention have been made in view of the above-described circumstances.

Exemplary aspects of the present invention provide an image forming apparatus that can effectively enhance transferability of a toner image by applying ultrasonic vibration to an endless transfer belt, more particularly, to a transfer nip where a secondary transfer electric field is generated on the endless transfer belt.

In one exemplary embodiment, an image forming apparatus includes a first endless transfer belt, first extension members, a first transfer electric field generator, a secondary transfer unit, and an ultrasonic vibration generator. The first endless transfer belt to carry a toner image thereon after a primary image transfer operation onto a surface thereof during rotation of the first endless transfer belt. The first extension members around which the first endless transfer belt was extended. The first transfer electric field generator is disposed inboard of the first endless transfer belt. The secondary transfer unit is disposed outboard of and at least partially faces the first endless transfer belt to transfer the toner image onto a transfer medium conveyed by the secondary transfer unit. The ultrasonic vibration generator generates ultrasonic vibrations and is disposed inboard of the first endless transfer belt. The ultrasonic vibration generator includes a vibration imparting part from which the ultrasonic vibration is applied to an inner face of the first endless transfer belt. The secondary transfer unit is disposed facing and in contact with a first surface portion of the first endless transfer belt to form a transfer nip therebetween, through which the transfer medium is conveyed when the toner image is transferred onto the transfer medium in a secondary image transfer operation. The transfer nip forms a transfer electric field due to a difference in electric potential between the first endless transfer belt and the secondary transfer unit. The first transfer electric field generator contacts the inner face of the first surface portion of the first endless transfer belt in the transfer nip and presses against the first endless transfer belt at a position along the first endless transfer belt in the transfer nip other than a position disposed opposite the secondary transfer unit with the first endless transfer belt interposed therebetween. The vibration imparting part of the ultrasonic vibration generator contacts the first endless transfer belt at a position intermediate between the first transfer electric field generator and the secondary transfer unit in a direction of rotation of the first endless transfer belt.

The secondary transfer unit may include a secondary transfer roller that contacts the first endless transfer belt directly to form the transfer nip therebetween to perform the secondary image transfer operation.

At least one of the first extension members around which the first endless transfer belt may be extended may constitute the first transfer electric field generator forming multiple first transfer electric field generators. The secondary transfer roller may be disposed at a position intermediate between the multiple first transfer electric field generators in a direction of rotation of the first endless transfer belt.

The ultrasonic vibration imparting part of the ultrasonic vibration generator may be disposed at a position upstream from the secondary transfer roller in a direction of rotation of the first endless transfer belt and may contact the inner face of the first endless transfer belt in the transfer nip.

The ultrasonic vibration imparting part of the ultrasonic vibration imparting part of the ultrasonic vibration generator may be between one of the multiple first transfer electric field generators and the secondary transfer roller.

The secondary transfer unit may further include a second endless transfer belt, second extending members around which the second endless transfer belt is extended to define multiple extended surface portions therebetween including a second surface portion, and a second transfer electric field generator disposed facing and in contact with an inner face of the second endless transfer belt in the transfer nip to contact the first endless transfer belt via the second endless transfer belt. The first extended surface portion of the first endless transfer belt and the second extended surface portion of the second endless transfer belt may form the transfer nip.

At least one of the first extension members around which the first endless transfer belt may be extended may constitute the first transfer electric field generator forming multiple first transfer electric field generators. The secondary transfer electric field generator may be disposed at a position intermediate between the multiple first transfer electric field generators in a direction of rotation of the first endless transfer belt.

The ultrasonic vibration imparting part of the ultrasonic vibration generator may be disposed upstream from the second transfer electric field generator in a direction of rotation of the first endless transfer belt and contacts the inner face of the first endless transfer belt.

The ultrasonic vibration imparting part of the ultrasonic vibration generator may be disposed between one of the multiple first transfer electric field generators and the secondary transfer electric field generator.

The second extending members that extend the second endless transfer belt may serve as a driven roller. A transfer electric field may be formed in a vicinity of an entrance of the transfer nip in the direction of rotation of the first endless transfer roller to attract the toner image carried on the surface of the first endless transfer belt and the second endless transfer belt to the first endless transfer belt.

One of the first extending members may extend the first endless transfer belt at an upstream end of the first extended surface portion and serves as a first upstream roller and one of the second extending members extends the second endless transfer belt at an upstream end of the second extended surface portion and serves as a second upstream roller. A difference in electric potential between the first upstream roller and the second upstream roller may attract the toner image carried on the first endless transfer belt and the second endless transfer belt to the first endless transfer belt.

The above-described image forming apparatus may further include multiple first transfer electric field generators including the first transfer electric field generator. The vibration imparting part of the ultrasonic vibration generator may contact the first endless transfer belt between two adjacent first transfer electric field generators of the multiple first transfer electric field generators that contact the first endless transfer belt.

The secondary transfer member may include a second transfer electric field generator to contact the first endless transfer belt between the two adjacent first transfer electric field generators.

The vibration imparting part of the ultrasonic vibration generator may contact the first endless transfer belt at a position upstream of the second transfer electric field generator in the direction of rotation of the first endless transfer belt.

At least one of a surface resistivity of an outer surface and a surface resistivity of an inner surface of the first endless transfer belt may fall within a range of from 1×10^{9}[Ω/square] to 1×10^{12} [Ω/square].

The transfer nip may transfer the toner image held on the first endless transfer belt onto a recording medium.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete appreciation of the disclosure and many of the attendant advantages thereof will be readily obtained as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings, wherein:

FIG. **1** is a schematic configuration of an image forming apparatus according to an exemplary embodiment of the present invention;

FIG. **2** is an enlarged view of a secondary transfer part of the image forming apparatus of FIG. **1** according to Exemplary Embodiment 1 of the present invention;

FIG. **3** is an enlarged view of a secondary transfer part of the image forming apparatus of FIG. **1** according to Exemplary Embodiment 2 of the present invention;

FIG. **4** is an enlarged view of a secondary transfer part of the image forming apparatus of FIG. **1** according to Modified Embodiment 1 of the present invention;

FIG. **5** is an enlarged view of a secondary transfer part of the image forming apparatus of FIG. **1** according to Modified Embodiment 2 of the present invention;

FIG. **6** is a schematic view illustrating an instrument used for measuring the combined volume resistivity of a roller member;

FIG. **7** is an enlarged view of a secondary transfer part of Comparative Example 1;

FIG. **8** is an enlarged view of an image forming apparatus for Comparative Example 2; and

FIG. **9** is an enlarged view of a secondary transfer part of the image forming apparatus of FIG. **8** of Comparative Example 2.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

It will be understood that if an element or layer is referred to as being "on", "against", "connected to" or "coupled to" another element or layer, then it can be directly on, against, connected or coupled to the other element or layer, or intervening elements or layers may be present. In contrast, if an element is referred to as being "directly on", "directly connected to" or "directly coupled to" another element or layer, then there are no intervening elements or layers present. Like numbers referred to like elements throughout. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items.

Spatially relative terms, such as "beneath", "below", "lower", "above", "upper" and the like may be used herein for ease of description to describe one element or feature's relationship to another element(s) or feature(s) as illustrated in the figures. It will be understood that the spatially relative terms are intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures. For example, if the device in the figures is turned over, elements describes as "below" or "beneath" other elements or features would then be oriented "above" the other elements or features. Thus, term such as "below" can encompass both an orientation of above and below. The device may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors herein interpreted accordingly.

Although the terms first, second, etc. may be used herein to describe various elements, components, regions, layers and/or sections, it should be understood that these elements, components, regions, layer and/or sections should not be limited by these terms. These terms are used only to distinguish one element, component, region, layer or section from another region, layer or section. Thus, a first element, component, region, layer or section discussed below could be termed a second element, component, region, layer or section without departing from the teachings of the present invention. The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the present invention. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "includes" and/or "including", when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

In describing exemplary embodiments illustrated in the drawings, specific terminology is employed for the sake of clarity. However, the disclosure of this patent application is not intended to be limited to the specific terminology so selected and it is to be understood that each specific element includes all technical equivalents that operate in a similar manner.

Referring now to the drawings, wherein like reference numerals designate identical or corresponding parts throughout the several views, exemplary embodiments of the present invention are described.

Now, exemplary embodiments of the present invention are described in detail below with reference to the accompanying drawings.

Descriptions are given, with reference to the accompanying drawings, of examples, exemplary embodiments, modification of exemplary embodiments, etc., of an image forming apparatus according to the present invention. Elements having the same functions and shapes are denoted by the same reference numerals throughout the specification and redundant descriptions are omitted. Elements that do not require descriptions may be omitted from the drawings as a matter of convenience. Reference numerals of elements extracted from the patent publications are in parentheses so as to be distinguished from those of exemplary embodiments of the present invention.

The present invention includes a technique applicable to any image forming apparatus. For example, the technique of the present invention is implemented in the most effective manner in an electrophotographic image forming apparatus.

In describing preferred embodiments illustrated in the drawings, specific terminology is employed for the sake of clarity. However, the disclosure of the present invention is not intended to be limited to the specific terminology so selected and it is to be understood that each specific element includes all technical equivalents that operate in a similar manner.

Referring now to the drawings, wherein like reference numerals designate identical or corresponding parts throughout the several views, preferred embodiments of the present invention are described.

FIG. **1** is a drawing of a schematic configuration of an image forming apparatus **500** according to an exemplary embodiment of the present invention.

The image forming apparatus **500** of FIG. **1** corresponds to a printer, copier, facsimile machine, etc. and employs a tandem type indirect transfer system. The image forming apparatus **500** mainly includes a tandem type image forming mechanism **100** and a transfer unit **200**.

The tandem type image forming mechanism **100** of the image forming apparatus **500** includes multiple image forming units **101**Y, **101**M, **101**C, and **101**K that are disposed along an intermediate transfer belt **20** that serves as an endless intermediate transfer member.

The transfer unit **200** of the image forming apparatus **500** is located at a center part thereof. The transfer unit **200** transfers respective toner images formed by the image forming units **101**Y, **101**M, **101**C, and **101**K onto a transfer sheet S serving as a recording medium. The transfer unit **200** includes the intermediate transfer belt **20** in a form of an endless belt member. The intermediate transfer belt **20** is wound around multiple extension rollers, which are a first extension roller **201**, a second extension roller **202**, and a transfer area entrance roller **203**, a transfer area exit roller **204**, a cleaning unit supporting roller **206**, and a third extension roller **207**. The intermediate transfer belt **20** is rotationally conveyable in a counterclockwise direction as indicated by arrow A in FIG. **1**.

A belt cleaning unit **210** is disposed facing the cleaning unit supporting roller **206** of the multiple extension rollers in FIG. **1**, with the intermediate transfer belt **20** interposed between the cleaning unit supporting roller **206** and the belt cleaning unit **210**. The belt cleaning unit **210** removes residual toner remaining on an outer surface or outer circumferential surface of the intermediate transfer belt **20** after a secondary image transfer operation of the toner image to the transfer sheet S.

The four image forming units **101**Y, **101**M, **101**C, and **101**K for colors of yellow (Y), magenta (M), cyan (C), and black (K), respectively, are located above the intermediate transfer belt **20**, particularly above an extended area ranging between the first extension roller **201** and the second extension roller **202**, and are arranged side by side along a direction of rotation of the intermediate transfer belt **20**. The image forming units **101**Y, **101**M, **101**C, and **101**K are removably installable to the image forming apparatus **500**. The image forming units **101**Y, **101**M, **101**C, and **101**K constitute the tandem type image forming mechanism **100**.

The image forming units **101**Y, **101**M, **101**C, and **101**K of the tandem type image forming mechanism **100** have substantially the same configuration, and therefore the configuration of the image forming unit **101** will also be explained without suffixes, as shown in FIG. **2**.

The image forming unit **101** illustrated in FIG. **1** includes a drum-shaped photoconductor **10** (e.g., drum-shaped photoconductors **10**Y, **10**M, **100**, and **10**K in FIG. **1**), a charging unit **103** (e.g., charging units **103**Y, **103**M, **103**C, and **103**K in FIG. **1**), an optical writing unit **110** (e.g., optical writing units **110**Y, **110**M, **110**C, and **110**K in FIG. **1**), and a developing unit **104** (e.g., developing units **104**Y, **104**M, **104**C, and **104**K). The photoconductor **10** serves as an image carrier for forming and carrying a toner image on a surface thereof. The charging unit **103**, the optical writing unit **110**, and the developing unit **104** are image forming components arranged around the photoconductor **10** for forming the toner image on the surface of the photoconductor **10**.

The charging unit **103** uniformly charges the surface of the photoconductor **10**. The charging unit **103** of FIG. **1** employs a charging roller serving as a charging member to which a direct current voltage is applied. As an alternative to the charging roller, the charging unit **103**K can employ a charging brush, and electrifying charger, or the like.

The optical writing unit **110** is an exposing unit of a LED writing system including a light emitting diode (LED) array and a lens array arranged in an axial direction or a main scanning direction of the photoconductor **10** in FIG. **1**. The optical writing unit **110** emits a laser light beam L according to an image signal to form an electrostatic latent image on the surface of the photoconductor **10**. Other than the optical writing unit **110**, it is also possible to use an optical writing unit of a laser scanning system including a laser beam source, a light deflector such as a rotary polygon mirror, and an image scanning optical system.

The developing unit **104** includes a developing roller that rotates while carrying a developer, and agitating and conveying member(s) that may agitate the developer and convey the developer to the developing roller. The developing unit **104** develops an electrostatic latent image formed on the surface of the photoconductor **10** with toner contained in the developer into a visible toner image. Regarding the type of developer, either single-component developer consisting essentially of toner or two-component developer consisting of toner and magnetic carrier is used.

The toner image that is formed on the surface of the photoconductor **10** through operations performed by the charging unit **103**, the optical writing unit **110**, and the developing unit **104** is transferred onto an outer surface of the intermediate transfer belt **20** in a primary image transfer area or an area or portion where the primary image transfer operation is performed.

A primary transfer roller **105** (e.g., primary transfer rollers **105**Y, **105**M, **105**C, and **105**K) that serves as a primary transfer member is disposed at a position in the primary image transfer area that is located opposite the photoconductor **10**, with the intermediate transfer belt **20** interposed between the primary transfer roller **105** and the photoconductor **10**. A transfer bias is applied to the primary transfer roller **105** with a DC power supply. In the primary image transfer area, the toner image formed on the surface of the photoconductor **10** is transferred onto the surface of the intermediate transfer belt **20** due to a difference in electric potential between the photoconductor **10** and the primary transfer roller **105** to which the transfer bias is applied.

Further, a photoconductor cleaning unit **106**, which removes residual toner remaining on the surface of the photoconductor **10** after the primary image transfer operation, is provided on a downstream side of the primary image transfer area in a direction of rotation of the photoconductor **10**.

When performing color image forming in the tandem type image forming mechanism **100** described above, the image forming units **101**Y, **101**M, **101**C, and **101**K for yellow (Y), magenta (M), cyan (C), and black (K) form respective single toner images of yellow (Y), magenta (M), cyan (C), and black (K) on the photoconductors **10**Y, **10**M, **100**, and **10**K, respectively. The image forming units **101**Y, **101**M, **101**C, and **101**K transfer the respective single toner images onto the intermediate transfer belt **20** to overlay the respective single toner images one on top of another to form a composite color image. When forming a black and white image, only the image forming unit **101**K for black (K) operates to form a monochrome image and transfer the monochrome image onto the surface of the intermediate transfer belt **20**.

By contrast, a secondary transfer mechanism **30** including a secondary image transfer area is located outboard of the intermediate transfer belt **20** and on the opposite side to the tandem type image forming mechanism **100**, with the intermediate transfer belt **20** interposed therebetween. The secondary transfer mechanism **30** includes a transfer sheet conveyance belt **300**.

The transfer sheet conveyance belt **300** serves as an endless transfer belt and is wound around two conveyance belt extension rollers, which are a first conveyance belt extension roller **301** and a second conveyance belt extension roller **302**.

Further, a conveyance belt cleaning unit **303** is disposed facing the second conveyance belt extension roller **302** via the transfer sheet conveyance belt **300**.

In the image forming apparatus **500**, a secondary image transfer nip N is formed in a contact area between an extended surface portion of the outer surface of the intermediate transfer belt **20** extended between the transfer area entrance roller **203** and the transfer area exit roller **204** and an extended surface portion of an outer surface of the transfer sheet conveyance belt **300** extended between the first conveyance belt extension roller **301** and the second conveyance belt extension roller **302**. A secondary transfer roller **304** is disposed in contact with an inner surface of the transfer sheet conveyance belt **300** in the secondary image transfer nip N. The transfer sheet S is conveyed to the secondary image transfer nip in synchronization of movement of the intermediate transfer belt **20** having the toner image thereon to the secondary image transfer nip N, so that the toner image on the intermediate transfer belt **20** can be transferred onto the transfer sheet S conveyed by the transfer sheet conveyance belt **300**.

A sheet feeding mechanism **150** that includes a sheet feeding cassette **151** and a sheet pickup roller **152**, a pair of sheet feeding rollers **153**, a pair of registration rollers **154**, a sheet conveyance guide path **155** is provided upstream from the secondary image transfer nip N of the secondary transfer mechanism **30** in a direction of conveyance of the transfer sheet S.

Further, a conveyance unit **156**, a fixing unit **107**, a pair of sheet discharging rollers **108**, a sheet stacker **109** are provided downstream from the secondary image transfer nip N of the secondary transfer mechanism **30**. The conveyance unit **156** conveys the transfer sheet S having the toner image transferred thereon. The fixing unit **107** fixes the transferred toner image to the transfer sheet S. The pair of sheet discharging rollers **108** discharges the transfer sheet S after fixing, to the sheet stacker **109**.

Next, a detailed description is given of image forming performed by the image forming apparatus **500** having the above-described configuration.

When a start switch of an operation unit, not illustrated, is pressed, a drive motor, not illustrated, rotates the second extension roller **202** to move the intermediate transfer belt **20** in the direction A of FIG. **1**. At the same time, the other two extension rollers are rotated with the one extension roller, whereby the intermediate transfer belt **20** is rotated. The rotation of the intermediate transfer belt **20** rotates the first extension roller **201**, the transfer area entrance roller **203**, and the transfer area exit roller **204**. In this exemplary embodiment, the second extension roller **202** serves as a drive roller. However, the drive roller can be any of the first extension roller **201**, the transfer area entrance roller **203**, and the transfer area exit roller **204** of the multiple extension rollers.

At the same time the intermediate transfer belt **20** starts to move, the photoconductors **10**Y, **10**M, **10**C, and **10**K serving as image carriers are rotated by respective drive motors, not illustrated, in the image forming units **101**Y, **101**M, **101**C, and **101**K of the respective colors. Single color images of yellow, magenta, cyan, and black are formed on the photoconductors **10**Y, **10**M, **100**, and **10**K, respectively. According to the movement of the intermediate transfer belt **20**, these single color images are sequentially transferred onto the intermediate transfer belt **20** to be overlaid one on top of another in the primary image transfer area. As a result, a composite full-color image is formed on the intermediate transfer belt **20**.

Further, when the start switch is pressed, the sheet pickup roller **152** is rotated and a sheet-like recording medium such as the transfer sheet S is fed out from the sheet feeding cassette **151** and guided to the sheet conveyance guide path **155**. The transfer sheet S is further conveyed toward the pair of registration rollers **154** and stopped when the transfer sheet S contacts the pair of registration rollers **154**.

Thereafter, the pair of registration rollers **154** rotates in synchronization with movement of the composite full-color image held by the intermediate transfer belt **20**. The transfer sheet S is conveyed to a position between the extended surface portion of the intermediate transfer belt **20** extended by the transfer area entrance roller **203** and the transfer area exit roller **204** and the extended surface portion of the transfer sheet conveyance belt **300** extended by the first conveyance belt extension roller **301** and the second conveyance belt extension roller **302**. Then, the full-color image is transferred onto the transfer sheet S due to the action of a secondary transfer electric field or ultrasonic vibrations, which will be described later.

According to the rotation of the transfer sheet conveyance belt **300**, the transfer sheet S passing through the secondary image transfer nip is conveyed to a position where the second conveyance belt extension roller **302** contacts the inner face of the transfer sheet conveyance belt **300** for extension, and then is further conveyed to a conveyance belt **156***a* of the conveyance unit **156**.

Thereafter, the transfer sheet S enters a fixing nip formed between a pressure roller and a fixing roller provided in the fixing unit **107** according to the rotation of the conveyance belt **156***a*, and then the unfixed toner image is fixed to the transfer sheet S by application of heat and pressure. The transfer sheet S having the toner image fixed thereto is discharged out of a main body of the image forming apparatus **500** guided by the pair of sheet discharging rollers **108** to the sheet stacker **109**.

Next, detailed descriptions are given of the configuration of the secondary transfer mechanism **30** of the image forming apparatus **500**.

[Exemplary Embodiment 1]

FIG. **2** is an enlarged view of the secondary transfer mechanism **30** that can be applied to the image forming apparatus **500** according to a first exemplary embodiment of the present invention. Hereinafter, the first exemplary embodiment is referred to as "Exemplary Embodiment 1".

As described above, the secondary transfer mechanism **30** includes the secondary image transfer nip N formed between the extended surface portion of the intermediate transfer belt **20** extended by the transfer area entrance roller **203** and the transfer area exit roller **204** and the extended surface portion of the transfer sheet conveyance belt **300** that faces the extended surface portion of the intermediate transfer belt **20**. Hereinafter, the extended surface portion of the intermediate transfer belt **20** extended by the transfer area entrance roller **203** and the transfer area exit roller **204** is referred to as an image conveyance belt extended surface portion **20***a* and the extended surface portion of the transfer sheet conveyance belt **300** facing the intermediate transfer belt **20** is referred to as a sheet conveyance belt extended surface portion **300***a*.

As shown in FIG. **2**, the image forming apparatus **500** according to Exemplary Embodiment 1 further includes an upper secondary transfer power source V**1**, a lower secondary transfer power source V**2**, a voltage applying brush **205**, the secondary transfer roller **304**, and an ultrasonic vibration generating unit **400**.

As shown in FIGS. **1** and **2**, the lower secondary transfer power source V**2** applies to the transfer area exit roller **204**, a bias voltage having a negative charge polarity that is same as toner.

The upper secondary transfer power source V**1** applies to the voltage applying brush **205**, a bias voltage having a negative charge polarity that is same as toner. The voltage applying brush **205** contacts the back side of the image conveyance belt extended surface portion **20***a* and is disposed upstream from the contact position where the transfer area exit roller **204** contacts the intermediate transfer belt **20** in the direction of rotation of the intermediate transfer belt **20**.

The secondary transfer roller **304** is electrically grounded. The secondary transfer roller **304** contacts the image conveyance belt extended surface portion **20***a* between the position where the transfer area exit roller **204** contacts the intermediate transfer belt **20** and the position where the voltage applying brush **205** contacts the intermediate transfer belt **20**, with the transfer sheet conveyance belt **300** interposed therebetween. Then, the secondary transfer electric field is generated due to a difference in electric potential between a member to which a bias voltage is applied, e.g., the transfer area exit roller **204** and the voltage applying brush **205**, and a grounded member, e.g., the secondary transfer roller **304**.

As described above, the transfer area entrance roller **203** extends the intermediate transfer belt **20** at the upstream side from the secondary image transfer nip N and is electrically grounded. The first conveyance belt extension roller **301** and the second conveyance belt extension roller **302** extend the transfer sheet conveyance belt **300**. Further, the second conveyance belt extension roller **302** is an insulating roller whose surface includes a high-resistance layer.

Both the first conveyance belt extension roller **301** and the second conveyance belt extension roller **302** are rotated with the transfer sheet conveyance belt **300**. Since the transfer sheet conveyance belt **300** closely contacts the intermediate transfer belt **20** at the secondary image transfer nip N, the transfer sheet conveyance belt **300** is rotated with the intermediate transfer belt **20** in a direction indicated by arrow B in FIG. **2** as the intermediate transfer belt **20** rotates in a direction indicated by arrow A in FIGS. **1** and **2**.

Further, the ultrasonic vibration generating unit **400** is disposed in the secondary transfer mechanism **30** of the image forming apparatus **500**. Specifically, the ultrasonic vibration generating unit **400** includes vibration transmission members **401** and **402**, a horn **403**, piezoelectric thin films **404** and **405**, an electrode **406**, and a vibration imparting part **407**. Details of these components will be described later.

The vibration imparting part **407** of the ultrasonic vibration generating unit **400** is disposed inboard of the intermediate transfer belt **20**, contacting a position P on the back side of the image conveyance belt extended surface portion **20***a*. The position P is located between the position where the voltage applying brush **205** contacts the intermediate transfer belt **20** and the position where the secondary transfer roller **304** contacts the intermediate transfer belt **20** via the transfer sheet conveyance belt **300**.

During image forming, the secondary transfer bias that has a negative charge polarity same as toner is applied to the transfer area exit roller **204** and the voltage applying brush **205**, and at the same time, ultrasonic vibrations are applied at the position P by the ultrasonic vibration generating unit **400** to a toner image T held on the intermediate transfer belt **20**. Application of ultrasonic vibrations can reduce an attraction force of the toner image T to the intermediate transfer belt **20**. The toner image T is then transferred onto the transfer sheet S by the secondary transfer electric field.

In the secondary transfer mechanism **30** according to Exemplary Embodiment 1, the secondary image transfer nip N ranges from the position where the first conveyance belt extension roller **301** contacts the intermediate transfer belt **20** via the transfer sheet conveyance belt **300** and the transfer area exit roller **204** contacts the transfer sheet conveyance belt **300** via the intermediate transfer belt **20**.

After passing the secondary image transfer nip N, the transfer sheet S is electrically discharged by a charge separation and isolation needle **305** to be separated from the transfer sheet conveyance belt **300**. The secondary transfer electric field is generated in a secondary transfer electric field generating area or an area from the voltage applying brush **205** to the transfer area exit roller **204** in the direction of rotation of the intermediate transfer belt **20**.

The voltage applying brush **205** includes a conductive brush, which is formed at the leading edge thereof and arranged in a vicinity of the position where the vibration imparting part **407** of the ultrasonic vibration generating unit **400** contacts the intermediate transfer belt **20** so as to slidably contact the inner surface of the intermediate transfer belt **20** as the intermediate transfer belt **20** rotates. A mylar sheet, which is not illustrated, is provided downstream from the position where the voltage applying brush **205** contacts the intermediate transfer belt **20** in the direction of rotation of the intermediate transfer belt **20** so that any component of the ultrasonic vibration generating unit **400** contacts the conductive brush of the voltage applying brush **205**.

Further, as shown in FIG. **2**, the secondary transfer roller **304** contacts at a position on the intermediate transfer belt **20** substantially upstream from a mid point of the contact area where the voltage applying brush **205** serving as an upstream secondary transfer bias applying member and the transfer area exit roller **204** serving as a downstream secondary transfer bias applying member on the intermediate transfer belt **20**.

The position where the secondary transfer roller **304** contacts the intermediate transfer belt **20** via the transfer sheet conveyance belt **300** is different from the position where the vibration imparting part **407** of the ultrasonic vibration generating unit **400** contacts the intermediate transfer belt **20**, and the secondary transfer roller **304** does not face the vibration imparting part **407** of the ultrasonic vibration generating unit **400**.

If the secondary transfer roller **304** and the vibration imparting part **407** are arranged to face each other via the intermediate transfer belt **20** and the transfer sheet conveyance belt **300**, ultrasonic vibrations are applied to the intermediate transfer belt **20** on a fixed area or an area supported by the secondary transfer roller **304** pressed against the intermediate transfer belt **20**. With this condition, the ultrasonic vibrations are not transmitted well and cannot contribute to the improvement of the toner image transferability, compared to the condition described in Exemplary Embodiment 1 that does not included a supporting member that supports the vibration imparting part **407** via the intermediate transfer belt **20** and the transfer sheet conveyance belt **300**.

In the configuration of Exemplary Embodiment 1, the secondary image transfer nip N is formed by one of the extended surface portions of the intermediate transfer belt **20** that serves as a toner image carrying belt and the contact area of the surface of the transfer sheet conveyance belt **300** that serves as a transfer sheet conveyance member.

Further, the transfer area exit roller **204** and the voltage applying brush **205**, both of which serve as the secondary transfer bias applying members, contact the inner side of the intermediate transfer belt **20**. More specifically, the transfer area exit roller **204** and the voltage applying brush **205** contact the image conveyance belt extended surface portion **20***a* that serves as an extended surface portion of the intermediate transfer belt **20** where the secondary image transfer nip N is formed. In the secondary image transfer nip N, the secondary transfer roller **304** that functions as a sheet transfer electric generating member contacts the image conveyance belt extended surface portion **20***a* via the transfer sheet conveyance belt **300** serving as a secondary transfer member.

Further, the position where the transfer area exit roller **204** contacts the intermediate transfer belt **20** and the position where the voltage applying brush **205** contacts the intermediate transfer belt **20** in the direction of rotation of the intermediate transfer belt **20** are different from the position where the secondary transfer roller **304** contacts the intermediate transfer belt **20** via the transfer sheet conveyance belt **300**.

Further, the vibration imparting part **407** of the ultrasonic vibration generating unit **400** serving as an ultrasonic vibration generator contacts the intermediate transfer belt **20** between the position where the voltage applying brush **205** contacts the intermediate transfer belt **20** and the position where the secondary transfer roller **304** contacts the intermediate transfer belt **20** via the transfer sheet conveyance belt **300**.

Thus, the vibration imparting part **407** of the ultrasonic vibration generating unit **400** contacts the position between the voltage applying brush **205** and the secondary transfer roller **304** on the intermediate transfer belt **20**, and therefore the ultrasonic vibrations can be applied to the intermediate transfer belt **20** within the area where the secondary transfer electric field is formed by the difference in electric potential between the voltage applying brush **205** and the secondary transfer roller **304**.

[Exemplary Embodiment 2]

FIG. **3** is an enlarged view of a secondary transfer mechanism **30'** that can be applied to the image forming apparatus **500** according to a second exemplary embodiment of the present invention. Hereinafter, the second exemplary embodiment is referred to as "Exemplary Embodiment 2".

As shown in FIG. **3**, the configuration of Exemplary Embodiment 2 is similar to the configuration of Exemplary Embodiment 1. Except that the configuration of the secondary transfer mechanism **30'** according to Exemplary Embodiment 2 further includes a transfer area entrance roller power source V**3** that applies a bias voltage having a charge polarity opposite the charge polarity of toner to the transfer area entrance roller **203**.

In the configuration of Exemplary Embodiment 2, the transfer area entrance roller power source V**3** applies a bias voltage of +1500 volts [V] to the transfer area entrance roller **203**.

Thus, by applying the bias voltage having the charge polarity opposite that of toner to the transfer area entrance roller **203**, the toner image T is attracted to the intermediate transfer belt **20** at the entrance of the secondary image transfer nip N. This application of the bias voltage to the transfer area entrance roller **203** at the entrance of the secondary image transfer nip N has prevented toner scattering on a toner image with texts, specifically toner scattering on a two-color toner image based on RGB image data effectively, compared to the configuration of Exemplary Embodiment 1.

Further, by applying this bias voltage, the electrostatic adhesiveness between the intermediate transfer belt **20**, the transfer sheet conveyance belt **300**, and the transfer sheet S have increased, the ultrasonic vibrations have been applied to the toner image more effectively, and good transfer performance without nonuniformity over the entire image has been achieved.

[Modified Embodiment 1]

Next, a description is given of a first modified exemplary embodiment of a secondary transfer mechanism **30**M. The configuration of the secondary transfer mechanism **30**M is different from the above-described configurations of the image forming apparatus **500** of Exemplary Embodiments 1 and 2. Hereinafter, the first modified exemplary embodiment is referred to as "Modified Exemplary Embodiment 1".

FIG. **4** is an enlarged view of a modified configuration of the secondary transfer mechanism **30**M according to Modified Exemplary Embodiment 1. Elements or components of the secondary transfer mechanism **30**M according to Modified Exemplary Embodiment 1 may be denoted by the same reference numerals as those of the secondary transfer mechanisms **30** and **30'** according to Exemplary Embodiments 1 and 2 and the descriptions thereof are omitted or summarized.

As shown in FIG. **4**, the configuration of Modified Exemplary Embodiment 1 is similar to the configuration of Comparative Embodiment shown in FIG. **7**. Except that the position where the secondary transfer roller **304** contacts the intermediate transfer belt **20** is changed to a further upstream side in the rotation of the intermediate transfer belt **20**, so that the vibration imparting part **407** of the ultrasonic vibration generating unit **400** contacts a position between a transfer roller opposed roller **214** and the secondary transfer roller **304** on the intermediate transfer belt **20**.

In this configuration of the secondary transfer mechanism **30**M, a transfer electric current is provided in a direction as indicated by arrow C in FIG. **4**, to the surface of the intermediate transfer belt **20**, between the transfer roller opposed roller **214** to which a transfer power source V**0** applies a bias voltage and the grounded secondary transfer roller **304** to form a transfer electric field, so that the toner image T carried by the intermediate transfer belt **20** is transferred onto the transfer sheet S.

The secondary transfer roller **304** is rotated with the rotation of the intermediate transfer belt **20**. That is, the secondary transfer roller **304** closely contacts the intermediate transfer belt **20** at the secondary image transfer nip N, and therefore the secondary transfer roller **304** is rotated with the intermediate transfer belt **20** in a direction indicated by arrow D in FIG. **4** as the intermediate transfer belt **20** rotates in the direction A.

In the configuration of the secondary transfer mechanism **30**M according to Modified Exemplary Embodiment 1, the secondary image transfer nip N is formed at a contact position between an extended surface portion extended by an upstream extension roller **213** and the transfer roller opposed roller **214** of the intermediate transfer belt **20** and the surface of the secondary transfer roller **304**. The transfer roller opposed roller **214** serving as a transfer electric field generating member contacts the intermediate transfer belt **20** from the back side of the image conveyance belt extended surface portion **20***a*, which is the extended surface portion of the intermediate transfer belt **20** forming the secondary image transfer nip N. In the secondary image transfer nip N, the secondary transfer roller **304** serving as the transfer sheet transfer electric field generating member contacts the image conveyance belt extended surface portion **20***a* directly.

Further, the position where the transfer roller opposed roller **214** contacts the intermediate transfer belt **20** in the direction of rotation of the intermediate transfer belt **20** is different from the position where the secondary transfer roller **304** contacts the intermediate transfer belt **20**. Further, the vibration imparting part **407** of the ultrasonic vibration generating unit **400** contacts the intermediate transfer belt **20** between the position where the transfer roller opposed roller **214** contacts the intermediate transfer belt **20** and the position where the secondary transfer roller **304** contacts the intermediate transfer belt **20**.

Thus, when the vibration imparting part **407** of the ultrasonic vibration generating unit **400** contacts the intermediate transfer belt **20** between the transfer roller opposed roller **214** and the secondary transfer roller **304**, ultrasonic vibrations can be applied to the intermediate transfer belt **20**, within the area where the secondary transfer electric field is generated due to the difference in electric potential between the transfer roller opposed roller **214** and the secondary transfer roller **304**.

Accordingly, this configuration can effectively enhance the toner image transferability, compared to Comparative

Example 1 shown in FIG. **7** and Comparative Example 2 shown in FIGS. **8** and **9**, which will be described later.

The configuration of Modified Exemplary Embodiment 1 illustrates a system employing an indirect transfer operation in which the secondary transfer roller **304** contacts the intermediate transfer belt **20**, on an area where no member or component is disposed facing the secondary transfer roller **304** via the intermediate transfer belt **20**. In such a system having the indirect transfer operation, the vibration imparting part **407** may contact the area between the transfer roller opposed roller **214** and the secondary transfer roller **304** from the back or inner side of the intermediate transfer belt **20**, as shown in FIG. **4**. In this configuration, however, a distance between the position where the secondary transfer roller **304** contacts the intermediate transfer belt **20** and the position where the transfer roller opposed roller **214** contacts the intermediate transfer belt **20** may increase.

Specifically, to arrange the vibration imparting part **407** to contact the intermediate transfer belt **20** within the area where the secondary transfer electric field is generated, the vibration imparting part **407** may need to contact the area between the contact position of the photoconductor transfer electric field generating member to the intermediate transfer belt **20** and the contact position of the secondary transfer member (e.g., the secondary transfer roller **304**) to the intermediate transfer belt **20**.

In Modified Exemplary Embodiment 1, the photoconductor transfer electric field generating member corresponds to the transfer roller opposed roller **214**. Therefore, even if the vibration imparting part **407** of the ultrasonic vibration generating unit **400** is arranged in a vicinity of the contact position of the transfer roller opposed roller **214** to the intermediate transfer belt **20**, the vibration imparting part **407** may be positioned away from the contact position of the transfer roller opposed roller **214** by at least the distance equal to the radius of the transfer roller opposed roller **214** from the position where the transfer roller opposed roller **214** contacts the intermediate transfer belt **20**. Therefore, the distance between the position where the secondary transfer roller **304** contacts the intermediate transfer belt **20** and the position where the transfer roller opposed roller **214** contacts the intermediate transfer belt **20** may be longer than an addition of the radius of the transfer roller opposed roller **214** and the width required for disposing the vibration applying part **407**. According to the reasons above, in the configuration of Modified Exemplary Embodiment 1, the distance between the position where the secondary transfer roller **304** contacts the intermediate transfer belt **20** and the position where the transfer roller opposed roller **214** contacts the intermediate transfer belt **20** increases.

As shown in the configuration of FIG. **5**, as the distance between the position where the secondary transfer roller **304** contacts the intermediate transfer belt **20** and the position where the transfer roller opposed roller **214** contacts the intermediate transfer belt **20** increases, a distance of which the electric current flows through the surface of the intermediate transfer belt **20** increases, and as a result, the surface resistivity of the intermediate transfer belt **20** prevents the flow of the electric current for transfer.

In the configuration of Modified Exemplary Embodiment 1, a transfer bias is applied to either the secondary transfer roller **304** or the transfer roller opposed roller **214** to flow the transfer electric current in the area between the secondary transfer roller **304** and the transfer roller opposed roller **214** on the intermediate transfer belt **20** for performing the secondary image transfer operation. Therefore, the transfer bias and the transfer electric current value depend on the distance between the secondary transfer roller **304** and the transfer roller opposed roller **214** and the surface resistivity of the intermediate transfer belt **20**. As the surface resistivity of the intermediate transfer belt **20** increases, the flow of the electric current is more resisted when performing a constant current control. This can increase the applied voltage, and as a result, the capacity of the power source can exceed its limits. Therefore, in the configuration of Modified Exemplary Embodiment 1, the constant current control of the secondary transfer bias may resist the flow of electric current, which can prevent the secondary image transfer operation.

Therefore, the volume resistivity and surface resistivity of the intermediate transfer belt **20** are determined according to voltages and electric currents in an acceptable range, and consequently, the surface resistivity of the intermediate transfer belt **20** in the configuration of Modified Exemplary Embodiment 1 employing the indirect transfer operation may be low. However, if the surface resistivity of the intermediate transfer belt **20** is low, the primary image transfer can have disadvantages according to the reasons described below.

Specifically, if the surface resistivity of the intermediate transfer belt **20** is low, the electric current flows smoothly through the surface of the intermediate transfer belt **20**. Therefore, a primary transfer bias applying member (e.g., the primary transfer roller **105** in FIG. **1**) applies a bias voltage to a wide area of the contact position, and the distribution of the transfer electric field can be wider. Generally in a primary transfer area, the primary transfer roller **105** is disposed to contact the intermediate transfer belt **20** at a position downstream from a primary image transfer nip formed between the photoconductor **10** and the intermediate transfer belt **20** so as to reduce the transfer electric field at the entrance of the primary transfer nip. However, even with this arrangement, if the distribution of the transfer electric field becomes wider by setting the surface resistivity of the intermediate transfer belt **20** to a lower value, the transfer electric field at the entrance of the primary image transfer nip increases. Since the toner image formed on the photoconductor **10** travels across a gap formed between the photoconductor **10** and the intermediate transfer belt **20** before being transferred onto the intermediate transfer belt **20**, toner scattering can occur more frequently. In addition, if the surface resistivity of the intermediate transfer belt **20** is low, the electric current flows across four primary transfer rollers **105** serving as multiple primary transfer bias application members, and it is likely to cause defect in bias control due to mutual interference of the electric current for the multiple primary transfer rollers **105**.

[Modified Exemplary Embodiment 2]

Next, a description is given of a second modified embodiment of a secondary transfer mechanism **30**M' in a configuration different from the above-described configurations of the image forming apparatus **500**. Hereinafter, the second modified embodiment is referred to as "Modified Exemplary Embodiment 2".

FIG. **5** is an enlarged view of a modified configuration of a secondary transfer mechanism **30**M' according to Modified Exemplary Embodiment 2. Elements or components of the secondary transfer mechanism **30**M' according to Modified Exemplary Embodiment 2 may be denoted by the same reference numerals as those of the secondary transfer mechanism **30**M according to Modified Exemplary Embodiment 1 and the descriptions thereof are omitted or summarized.

As shown in FIG. **5**, the configuration of Modified Exemplary Embodiment 2 is similar to the configuration of Modified Exemplary Embodiment 1 shown in FIG. **4**. Except that the secondary transfer roller **304** contacts the intermediate transfer belt **20** via the transfer sheet conveyance belt **300** that is extended by the first conveyance belt extension roller **301** and the second conveyance belt extension roller **302**. The configuration of Modified Exemplary Embodiment 2 also includes a secondary transfer roller power source V**4** to apply a bias voltage having a charge polarity opposite the charge polarity of toner, which is a negative polarity, to the secondary transfer roller **304**, and a secondary transfer bias applying member (e.g., the secondary transfer roller **304**) contacts the back side of the transfer sheet conveyance belt **300**. At least the second conveyance belt extension roller **302**, which is one of the rollers extending the transfer sheet conveyance belt **300**, is an insulating roller having a high-resistance layer as a surface thereof.

Further, the transfer area exit roller **204** serving as a transfer electric field generating member is electrically grounded, and a secondary transfer electric field is formed due to the difference in electric potential between the secondary transfer roller **304** and the transfer area exit roller **204**.

Similar to Modified Exemplary Embodiment 1, in the configuration of Modified Exemplary Embodiment 2, an extension roller on the downstream side of the image conveyance belt extended surface portion **20***a*, which corresponds to the transfer area exit roller **204** in Modified Exemplary Embodiment 2 and serves as a transfer electric field generating member, and the vibration imparting part **407** of the ultrasonic vibration generating unit **400** contacts at a position between the transfer area exit roller **204** and the secondary transfer roller **304** on the intermediate transfer belt **20**. According to the configuration, the distance between the position of the photoconductor transfer electric generating member (e.g., the transfer area exit roller **204**) contacting the intermediate transfer belt **20** and the sheet transfer member (e.g., the secondary transfer roller **304**) increases, which is likely to cause defects on toner images, similar to Modified Exemplary Embodiment 1.

As noted in the description of Modified Exemplary Embodiment 1, if the surface resistivity of the intermediate transfer belt **20** decreases, the toner scattering can occur easily before the primary image transfer nip. However, with the configuration of Modified Exemplary Embodiment 2, by reducing not the surface resistivity of the intermediate transfer belt **20** but the surface resistivity of the transfer sheet conveyance belt **300**, the flow of electric current from the secondary transfer roller **304** to the transfer area exit roller **204** can be enhanced, thereby effectively forming the secondary transfer electric field.

In the configuration of Modified Exemplary Embodiment 2, the surface resistivity of the transfer sheet conveyance belt **300** is lower than the surface resistivity of the intermediate transfer belt **20**. In this case, when a bias voltage is applied to the secondary transfer roller **304**, the electric current flows through the surface of the transfer sheet conveyance belt **300** in a direction indicated by arrow E shown in FIG. **5**, and therefore can further flow from the transfer sheet conveyance belt **300** toward the intermediate transfer belt **20** at the position where the transfer area exit roller **204** contacts the transfer sheet conveyance belt **300** via the intermediate transfer belt **20**. Therefore, a high transfer electric field to the toner image is generated at the position where the transfer area exit roller **204** is disposed facing the transfer sheet conveyance belt **300** via the intermediate transfer belt **20**, and a low transfer electric field to the toner image is generated at the position where the vibration imparting part **407** of the ultrasonic vibration generating unit **400** contacts the inner surface of the intermediate transfer belt **20**. Consequently, the configuration of Modified Exemplary Embodiment 2 can provide only a small effect of enhancement of the toner image transferability by applying the ultrasonic vibrations.

Modified Exemplary Embodiment 2 shows the configuration in which the bias voltage having the charge polarity opposite the charge polarity of toner is applied to the secondary transfer roller **304** while the transfer area exit roller **204** is electrically grounded, as shown in FIG. **5**.

However, as an alternative configuration, the secondary transfer roller **304** can be electrically grounded and the bias voltage having the charge polarity same as the charge polarity of toner can be applied to the transfer area exit roller **204**. With this configuration, even though the path of the flow of electric current from the transfer area exit roller **204** to the secondary transfer roller **304** is reversed, i.e. the electric current flows in a direction opposite the direction E in FIG. **5**, the electric current itself flows through the surface of the transfer sheet conveyance belt **300**. Therefore, similar to the original configuration of Modified Exemplary Embodiment 2, a high transfer electric field to the toner image is generated at the position where the transfer area exit roller **204** is disposed facing the transfer sheet conveyance belt **300** via the intermediate transfer belt **20**. Consequently, a low transfer electric field to the toner image is generated at the position where the vibration imparting part **407** of the ultrasonic vibration generating unit **400** contacts the inner surface of the intermediate transfer belt **20**, and as a result, this configuration can provide only a small effect of enhancement of the toner image transferability by applying the ultrasonic vibrations, compared to the configurations of Exemplary Embodiments 1 and 2.

In the configuration of Modified Exemplary Embodiment 2, the secondary image transfer nip N is formed by the image conveyance belt extended surface portion **20***a*, which is one of the extended surface portions of the intermediate transfer belt **20** serving as the endless toner image carrying belt, and the contact area of the extended surface portion **300***a* of the transfer sheet conveyance belt **300** serving as a secondary transfer member.

Further, the transfer area exit roller **204** serving as a transfer electric field generating member contacts the inner side of the intermediate transfer belt **20**, and more specifically, contacts the image conveyance belt extended surface portion **20***a* as a photoconductor transfer nip extended surface portion that serves as an extended surface portion of the intermediate transfer belt **20** where the secondary image transfer nip N is formed. In the secondary image transfer nip N, the secondary transfer roller **304** serving as a sheet transfer electric field generating member contacts the image conveyance belt extended surface portion **20***a* via the transfer sheet conveyance belt **300** serving as a transfer sheet conveyance member.

Further, the position where the transfer area exit roller **204** contacts the intermediate transfer belt **20** in the direction of rotation of the intermediate transfer belt **20** is separated from the position where the secondary transfer roller **304** contacts the intermediate transfer belt **20** via the transfer sheet conveyance belt **300**. Further, the vibration imparting part **407** of the ultrasonic vibration generating unit **400** contacts the intermediate transfer belt **20**, between the position where the transfer area exit roller **204** contacts the intermediate transfer belt **20** and the position where the secondary transfer roller **304** contacts the intermediate transfer belt **20** via the transfer sheet conveyance belt **300**.

Thus, since the vibration imparting part **407** of the ultrasonic vibration generating unit **400** contacts the position P between the transfer area exit roller **204** and the secondary transfer roller **304** on the intermediate transfer belt **20**, the ultrasonic vibrations can be applied to the intermediate transfer belt **20**, within the area where the secondary transfer electric field is formed by the difference in electric potential between the transfer area exit roller **204** and the secondary transfer roller **304**.

The configurations of Exemplary Embodiments 1 and 2 include the voltage applying brush **205** that serves as a secondary transfer electric field generating member used for contacting the vibration imparting part **407** and that is disposed between the contact position of the photoconductor transfer electric field generating member (e.g., the transfer area exit roller **204**) contacts the intermediate transfer belt **20** and the transfer sheet conveyance member (e.g., the secondary transfer roller **304**) contacts the intermediate transfer belt **20**. Therefore, the contact position of the vibration imparting part **407** to the intermediate transfer belt **20** can be adjacent the contact position of the voltage applying brush **205** to the intermediate transfer belt **20**. This allows the contact position of the secondary transfer roller **304** to the transfer sheet conveyance belt **300** to be arranged adjacent the contact position of the voltage applying brush **205**. Consequently, this configuration can prevent defects in Modified Exemplary Embodiments 1 and 2 caused by an increase in distance between the contact position of the photoconductor transfer electric field generating member and the transfer sheet conveyance member.

Next, a description is given of the ultrasonic vibration generating unit **400**, referring to FIG. **2**.

The ultrasonic vibration generating unit **400** is provided to apply ultrasonic vibrations to the intermediate transfer belt **20** forming a transfer nip so as to enhance the toner image transferability. The configuration of the ultrasonic vibration generating unit **400** includes, but is not limited to, the configuration shown in FIG. **2**.

As previously described, the ultrasonic vibration generating unit **400** incorporated in the image forming apparatus **500** includes the vibration transmission members **401** and **402**, the horn **403**, the piezoelectric thin films **404** and **405**, the electrode **406**, and the vibration imparting part **407**.

The ultrasonic vibration generating unit **400** incorporated in the image forming apparatus **500** is formed by a bolt-clamped Langevin transducer and an exponential horn that serves as an amplitude amplifier. The Langevin transducer is formed by piezoelectric thin films **404** and **405** having a same thickness are overlaid such that one direction of electrostriction is opposite the other, both ends of the two piezoelectric thin films **404** and **405** are sandwiched by the vibration transmission members **401** and **402**, which are generally formed by material having high vibration transmission ability, for example, metal such as aluminum and titanium, and bolt-clamped with bolts, not illustrated.

Langevin transducer has a length of $\lambda/2$ (half-wave) and can amplify vibration by resonance. Similarly, the horn **403** also uses resonance to amplify vibration.

The horn **403** has a length same as the width of the intermediate transfer belt **20** in an axial direction or a direction perpendicular to the direction of rotation of the intermediate transfer belt **20**. The horn **403** also includes a slit or slits in an axial direction thereof to prevent interference in the axial direction and apply vibration across the entire width of the intermediate transfer belt **20** uniformly. The vibration transmission members **401** and **402** and the horn **403** are electrically conducted via bolts, not illustrated.

The electrode **406** is disposed between the piezoelectric thin films **404** and **405** serving as transducers and a sine wave alternate current (AC) voltage is applied between the electrode **406** and the vibration transmission member **401**, thereby generating ultrasonic vibrations due to electrostriction.

The vibration imparting part **407** that corresponds to the tip of the horn **403** applies the vibration amplified by the piezoelectric thin films **404** and **405** and the horn **403** in a direction perpendicular to the surface of the intermediate transfer belt **20**.

The ultrasonic vibration generating unit **400** preferably applies, to the intermediate transfer belt **20**, frequency of vibration in a range of from 20 kilohertz [kHz] to 100 kilohertz [kHz] and amplitude at peak-to-peak in a range of from 0.1 micrometers [μm] to 10 micrometers [μm]. To enhance transferability by applying vibration to a toner image carrying belt, it is necessary to apply vibration by an amount that the toner on the toner image held on the intermediate transfer belt **20** cannot follow the vibrations, so as to reduce the attachment force of toner to the toner image carrying belt. Therefore, the frequency of the ultrasonic vibrations to be applied to the intermediate transfer belt **20** is 20 kilohertz [kHz] or greater. If the frequency of the ultrasonic vibrations to be applied to the intermediate transfer belt **20** is too large, the ultrasonic vibrations can trigger toner scattering. Therefore, the frequency of ultrasonic vibrations to be applied to the intermediate transfer belt **20** is set to 100 kilohertz [kHz] or smaller.

Further, the length of the horn **403** that serves as a resonance member varies according to the settings of the frequency used, i.e., as the frequency to be used is set higher, the length of the horn **403** can be shorter. Therefore, to downsize the apparatus, a high frequency of vibration may be set. However, if the frequency is too high, the toner cannot follow the vibrations, and therefore the effect of enhancement of toner image transferability may decrease. To prevent this, it may need to consider the size of the image forming apparatus (e.g., the image forming apparatus **500**) and set an appropriate frequency for the image forming apparatus.

Next, a description is given of the controls of the secondary transfer bias to be applied to the transfer area exit roller **204** and the voltage applying brush **205** for forming the secondary transfer electric field of the image forming apparatus **500**.

The transfer electric field control includes the constant current control and the constant voltage control. If an object that receives an image is a sheet of paper, the resistance of the sheet of paper largely changes depending on type, thickness, and size of the sheet of paper, environmental condition, and the like, and therefore it is preferable that the secondary transfer bias applied to the transfer area exit roller **204** and the voltage applying brush **205** is subject to constant-current controlling. In an exemplary embodiment of the present invention, voltages to be applied to the transfer area exit roller **204** and the voltage applying brush **205** may have the conditions identical to each other or different from each other.

In the image forming apparatus **500** according to an exemplary embodiment of the present invention, the transfer area exit roller **204** and the voltage applying brush **205**, which are two of the multiple secondary transfer bias applying members, are disposed on the inner surface of the intermediate transfer belt **20**. However, three or more of the multiple secondary transfer bias applying members can alternatively be disposed.

It is, however, difficult to provide the same distance between each of the multiple secondary transfer bias applying members and an opposed member (e.g., the secondary transfer roller **304** in the image forming apparatus **500**) to which the electric current from the multiple secondary transfer bias applying members can easily flow. With the different distances, it is difficult to have an equal resistance between the secondary transfer bias applying member and the opposed member, for example, the resistance of the intermediate transfer belt **20**. Since each secondary transfer bias applying member has different resistances with respect to the opposed member, it is preferable that the secondary transfer bias voltage has the constant current control.

When the resistance between the secondary transfer bias applying member and the opposed member increases, the applied voltage in the configuration having the constant current control can increase, and as a result, the capacity of power source reaches the upper limit. Therefore, it is necessary to perform the control considering the upper limit value of the capacity of power source and provide different set current values. In addition, with consideration of the separation ability of the transfer sheet S, it is possible to set the secondary transfer electric field on the upstream side to be high and the secondary transfer electric field on the downstream side to be low, according to the system.

The image forming apparatus **500** employs the voltage applying brush **205** serving as an upstream secondary transfer bias applying member and the transfer area exit roller **204** serving as a downstream secondary transfer bias applying member. However, the secondary transfer bias applying member of this configuration is not limited thereto. For example, a roller, a brush, a film or other conventional secondary transfer bias applying member can be used as the secondary transfer bias applying member used for the present invention. When the secondary transfer bias applying member contacts the intermediate transfer belt **20** adjacent the position where the vibration imparting part **407** of the ultrasonic vibration generating unit **400** contacts the intermediate transfer belt **20**, as shown in FIG. **2**, a brush or film member is preferably used as a secondary transfer bias applying member.

When the secondary image transfer nip is formed on the extended surface portion **20***a* of the intermediate transfer belt **20**, as in the configuration of the image forming apparatus **500**, either one of the two extension rollers that extend the intermediate transfer belt **20** at both ends of the extended surface portion forming the secondary image transfer nip can also be used as a secondary transfer bias applying member, which is preferable to reduce the size of the image forming apparatus **500**.

Further, when either one of the two extension rollers is used as the secondary transfer bias applying member, as in the configuration of the image forming apparatus **500**, the extension roller disposed on the downstream side in a direction of rotation of the intermediate transfer belt **20** (e.g., the transfer area exit roller **204** in the image forming apparatus **500**) of the two extension rollers is more preferably used according to the reasons described below.

Specifically, if the extension roller (e.g., the transfer area exit roller **204**) disposed on the downstream side of the extended surface portion of the intermediate transfer belt **20** is used as the secondary transfer bias applying member, the transfer bias is applied to the extension roller disposed in the area after the transfer sheet S closely contacts the intermediate transfer belt **20** that holds a toner image thereon. Therefore, even if an electric field is generated across the gap at the end of the secondary image transfer nip, the toner image may be affected only slightly.

By contrast, if an extension roller (e.g., the transfer area entrance roller **203**) disposed on the upstream side of the extended surface portion **20***a* of the intermediate transfer belt **20** is used as the secondary transfer bias applying member, the transfer bias is applied to the extension roller disposed in the area before the transfer sheet S closely contacts the intermediate transfer belt **20** with the toner image thereon, and therefore an electric field may be generated at the entrance of the secondary image transfer nip, resulting in occurrence of defective image such as transfer scattering.

The examples of the materials for the secondary transfer bias applying member include conductive materials such as metal materials can be used and electrically grounded via resistance. Further, the examples of the materials for a roller-shaped secondary transfer bias applying member include a metal shaft bar surrounded by a rubber material having a given resistivity. When the secondary transfer bias applying member is a transfer bias applying roller (e.g., the transfer area exit roller **204**), the roller-shaped member has a configuration such that an elastic layer made of, for example, an elastic material including an ion conducting agent and a conductive agent is added.

The specific examples of the materials used for the elastic layer that covers the metal shaft of the transfer bias applying member include rubbers having an ion-conducting property, such as epichlorohydrin rubbers, urethane rubbers, nitrile—butadiene rubbers, acrylic rubbers, chloroprene rubbers, fluorine-containing rubbers, nitrile rubbers, norbornene rubbers, etc., and other rubbers such as natural rubbers (NR), butadiene rubbers, isoprene rubbers, styrene—butadiene rubbers (SBR), ethylene—propylene—diene rubbers (EPDM), butyl rubbers, silicone rubbers, etc. These materials can be used alone or in combination. Among these materials, epichlorohydrin rubbers are preferably used because of having a good combination of ionic conductivity and physical properties.

A typical conductive brush can be used as the voltage applying brush **205**. For example, conductivity of such a conductive brush is obtained by adding carbon black as conductive agent to resin fibers such as acrylic resin, polyester resin, nylon resin, or the like. Various brush hairs or fibers having a conduction of uniform dispersion, a shape of core of a pencil, or a shape in which both sides of a conductive layer is sandwiched by resin materials according to the shape of conductive agent when the conductive agent was added can be used.

Next, a description is given of the intermediate transfer belt **20**.

The intermediate transfer belt **20** may have a single-layered structure or a multi-layered structure. In addition, the method for preparing the intermediate transfer belt **20** is not particularly limited, and any known methods such as dipping methods, centrifugal molding methods, extrusion molding methods, inflation methods, coating methods, and spraying methods can be used.

The surface layer, which is a thin layer of the composite belt, can be prepared by any suitable known methods. Specific examples of typical methods are, but not limited to, spray coating methods, dip coating methods, and flow coating methods. When using a centrifugal molding method, for example, after molding and drying the upper layer, the base layer is formed, dried, and cured.

Suitable materials for use in preparing a base layer of the intermediate transfer belt **20** include polyimide resins, polyamide imide resins, polycarbonate resins, polyphenylene sulfide resins, polyurethane resins, polybutylene terephthalate resins, polyvinylidene fluoride resins, polysulfone resins, polyether sulfone resins, polymethyl pentene resins, and combinations thereof. In view of the strength, polyimide resins, and polyamide imide resins are preferably used. It is preferable to add an electro conductive carbon black to the intermediate transfer belt to control the resistivity thereof.

Next, an example of the centrifugal molding method for preparing the intermediate transfer belt **20** using a polyimide resin will be explained.

Polyimide resins are typically prepared by subjecting an aromatic polycarboxylic anhydride (or a derivative thereof) and an aromatic diamine to a condensation reaction. Because of having a rigid main chain, such polyimide resins are insoluble in solvents and are not melted even when heated. Therefore, at first, a polyamic acid (i.e., a polyamide acid or an aromatic polyimide precursor), which can be dissolved in an organic solvent, is prepared by reacting an anhydride with an aromatic diamine. After the polyamic acid (or the like) is molded by any known methods, the molded polyamic acid is heated or subjected to a chemical treatment to perform dehydration and ring formation (i.e., imidization). Thus, a molded polyimide resin is prepared.

Specific examples of the aromatic polycarboxylic anhydrides include ethylenetetracarboxylic dianhydride, cyclopentanetetracarboxylic dianhydride, pyromellitic anhydride, 3,3',4,4'-benzophenonetetracarboxylic dianhydride, 3,3',4,4'-biphenyltetracarboxylic dianhydride, etc., but are not limited thereto. These compounds can be used alone or in combination.

Specific examples of the aromatic diamines include m-phenylenediamine, o-phenylenediamine, p-phenylenediamine, m-aminobenzylamine, p-aminobenzylamine, 4,4'-diaminodiphenyl ether, 3,3'-diaminodiphenyl ether, 3,4'-diaminodiphenyl ether, etc., but are not limited thereto. These compounds can be used alone or in combination.

By polymerizing an aromatic polycarboxylic anhydride with a diamine, which are mixed in a molar ratio of approximately 1:1, in a polar organic solvent, a polyimide precursor (i.e., a polyamic acid) can be prepared.

Suitable solvents for use as the polar organic solvent includes any known polar organic solvents, which can dissolved a polyamic acid, and N,N-dimethylformamide and N-methyl-2-pyrrolidone are preferably used.

Although it is easy to synthesize a polyamic acid, various polyimide varnishes in which a polyamic acid is dissolved in an organic solvent are marketed. Specific examples of such varnishes include TORAYNEECE (from Toray Industries Inc.), U-VARNISH (from Ube industries, Ltd.), RIKACOAT (from New Japan Chemical Co., Ltd.), OPTOMER (from Japan Synthetic Rubber Co., Ltd.), SE812 (from Nissan Chemical Industries, Ltd.), CRC8000 (from Sumitomo Bakelite Co., Ltd.), etc.

Specific examples of the resistivity controlling agents for use in the polyimide resins include powders of electroconductive resistivity controlling agents such as carbon black, graphite, metals (e.g., copper, tin, aluminum, and indium), metal oxides (e.g., tinoxide, zincoxide, titaniumoxide, indium oxide, antimony oxide, bismuth oxide, tin oxide doped with antimony, and indium oxide doped with tin), etc.

In addition, ion-conducting resistivity controlling agents can also be used. Specific examples thereof include tetraalkylammonium salts, trialkylbenzyl, ammonium salts, alkylsulfonic acid salts, alkylbenzenesulfonic acid salts, alkylsulfates, esters of glycerin and a fatty acid, esters of sorbitan and a fatty acid, polyoxyethylenealkylamine, esters of polyoxyethylenealiphatic alcohols, alkylbetaine, lithium perchlorate, etc., but are not limited thereto.

Among these resistivity controlling agents, carbon black is preferably used for polyimide resins.

The thus prepared polyamic acid is heated at a temperature of from approximately 200 degrees Celsius to approximately 350 degrees Celsius to be converted to a polyimide resin.

By contrast, when continuous melt extrusion molding methods are used, thermoplastic resins are preferably used. Specific examples of such thermoplastic resins include polyethylene, polypropylene, polystyrene, polybutylene terephthalate (PBT), polyethylene terephthalate (PET), polycarbonate (PC), ethylene—tetrafluoroethylene copolymers (ETFE), polyvinylidene fluoride (PVdF), etc.

Melt molding methods are not limited but broadly classified into continuous melt extrusion molding methods, injection molding methods, blow molding methods, inflation molding methods, etc. Among these methods, continuous melt extrusion molding methods are preferably used for preparing a seamless belt.

Carbon black is typically used as an electroconductive agent for the intermediate transfer belt **20**. The dispersion state of a carbon black, which is prepared by kneading, in a belt formed by a melt extrusion method is typically inferior to that in a belt formed by a centrifugal method using a dispersion in which a carbon black is dispersed in high conductive agents. Therefore, the variation of resistivity of a belt formed by a melt extrusion method is typically larger than that of a belt formed by a centrifugal method.

A material suitable for the surface layer of the intermediate transfer belt **20** is not limited to a specific material but is demanded to be a material to reduce an adhesion force of toner to the outer circumference of the intermediate transfer belt **20** and to increase secondary transferability.

Suitable examples of materials of the surface layer of the intermediate transfer belt **20** are, but not limited to, resin materials such as polyurethane, polyester, polyamide, etc. A coat layer including these resin materials can be obtained as a resin coat film by a curing agent such as isocyanato, melamine, silane coupling agent, and carbodiimide. Further, by filling a mold releasing filler, such as polytetrafluoroethylene (PTFE), silica, molybdenum disulfide, and carbon black, the coat layer can increase mold releasing performance of the surface thereof to improve the cleaning performance and prevent accumulation of toner and discharge product material. Further, the coat layer can include conductive fillers (conductive agents), such as conductive carbon black, tin oxide, zinc oxide to control the resistance. Further, the coat layer can include surface active agents, such as fluorine-containing surface active agent, silicone-containing surface active agent, nonion-containing surface active agent to uniformly mixing and dispersing these fillers.

One or more polyurethane resin, polyester resin, epoxy resins, etc. can be used as materials of the surface layer of the intermediate transfer belt **20**. Further, lubrication must be high by reducing the surface energy. Therefore, one or more powders or particles of fluorine resin, fluorine compound, carbon fluoride, titanium dioxide, and silicon carbide can be dispersed in the layer; or the same kinds of the above material whose particle diameter is different can be dispersed in the layer. In addition, similar to fluorine containing rubber materials, the surface energy can be reduced by forming a fluorine-rich layer on the outer circumference of the intermediate transfer belt **20** by applying heat treatment. Carbon black can be used for resistance controlling.

Next, a description is given of examples of manufacturing the intermediate transfer belt **20** and the transfer sheet conveyance belt **300** according to an exemplary embodiment of the present invention. Specific examples of typical materials and manufacturing methods of the intermediate transfer belt **20** and the transfer sheet conveyance belt **300** used in the image forming apparatus **500** according to an exemplary embodiment are, but not limited to, the following.

The intermediate transfer belt **20** and the transfer sheet conveyance belt **300** used in the image forming apparatus **500** according to an exemplary embodiment are formed by polyimide resin, manufactured in a belt shape using a centrifugal molding technique and applied different resistivities.

Polymerization of 3,3',4,4'-biphenyl tetracarboxylic acid dianhydride as the aromatic polyhydric carboxylic anhydride, p-phenylenediamine as the aromatic diamine, and N-methyl-2-pyrrolidone as the organic polar solvent was performed to obtain a polyamic acid solution. Acetylene black was added to the polyamic acid solution, to the amount of 17% to the solid content density thereof. The mixture is agitated with Aquamizer manufactured by HOSOKAWA MICRON CORPORATION. Thus, polyamic acid having 18% of solid content as precursor of polyimide resin was prepared.

The polyamic acid obtained as above was molded into a ring or loop through a centrifugal molding method while a metal cylindrical mold having a diameter of 375 mm was rotated at a speed of 100 rpm, and polyamic acid having a solid content of 19% was uniformly applied to an inner surface of the cylindrical mold by a dispenser. Next, the cylindrical mold was rotated at a speed of 1000 rpm for 5 minutes to level the polyamic acid. Then, the rotation speed was reduced to 300 rpm, and the cylindrical mold was gradually heated to 130 degrees Celsius. The polyamic acid was dried for 40 minutes and was solidified.

After the solidification, the cylindrical mold was stopped to rotate and heated to 350 degrees Celsius, to cause imide ring-closing. Thus, imidization was completed and polyimide coating was obtained.

Next, the cylindrical mold was cooled to room temperature and the polyimide coating was removed therefrom. Both edges of the polyamic coating were cut off so that the polyamic coating had a width of 365 mm. From the above, a seamless intermediate transfer belt **20** having a layer thickness of 80 micrometers [μm] was produced. The resistance of the intermediate transfer belt **20** was adjusted by a conductive additive amount (carbon black). The resistance can be adjusted under the primary dry condition, however, adjustment of resistance for one or more digits may need to be performed according to type and amount of carbon black.

Further, a belt position guide that is formed by polyurethane resin and has a thickness of 1.0 millimeters [mm] and a width of 5 millimeters [mm] is provided with double-faced adhesive tape at both ends in a widthwise direction of an outer circumferential surface of the intermediate transfer belt **20**.

[Test]

Tests were conducted to examine whether the transferability of an image can be improved by applying ultrasonic vibrations to the intermediate transfer belt **20** and how other image characteristics are affected.

Table 1 shows test results obtained by apparatuses having a configuration of Exemplary Embodiment 1 or Exemplary Embodiment 2 and an apparatus having a configuration of Modified Exemplary Embodiment 2 as Comparative Condition 5.

Table 2 shows tests results obtained by apparatuses having a configuration of Modified Exemplary Embodiment 1, Comparative Example 1 according to FIG. **7** and Comparative Example 2, which is described below.

TABLE 1

		EC1	EC2	EC3	EC4	CC5
FIG		FIG. 2	FIG. 3	FIG. 3	FIG. 3	FIG. 5
Intermediate Transfer Belt 20	Material	Polyimide	Polyimide	Polyimide	Polyimide	Polyimide
	Thickness	80 [μm]	80 [μm]	80 [μm]	80 [μm]	80 [μm]
	Surface Resistivity	10.5	10.5	9.2	11.8	11.5
	Volume Resistivity	8.8	8.8	8.5	9.5	9.1
Transfer Sheet Conveyance Belt 300	Material	Polyimide	Polyimide	Polyimide	Polyimide	Polyimide
	Thickness	80 [μm]	80 [μm]	80 [μm]	80 [μm]	80 [μm]
	Surface Resistivity	10.5	10.5	10.5	10.5	9.5
	Volume Resistivity	8.8	8.8	8.8	8.8	8.5
Transfer area exit roller 204	Material	NBR Coated	NBR Coated	NBR Coated	NBR Coated	Foamed Polyurethane
	Resistance	6.8	6.8	7.5	8	6.5
	Bias	30 [μA]	30 [μA]	27 [μA]	25 [μA]	Grounded
Voltage Applying Brush 205	Material	Conductive Acrylic Fiber	Conductive Acrylic Fiber	Conductive Acrylic Fiber	Conductive Acrylic Fiber	
	Bias	35 [μA]	35 [μA]	35 [μA]	35 [μA]	
Transfer Area Entrance Roller 203	Material	Metal	Metal	Metal	Metal	Metal
	Resistance	—	—	—	—	—
	Bias	Grounded	Plus 1500 [V]	Plus 2000 [V]	Plus 1200 [V]	Grounded
First Conveyance Belt Extension Roller 301	Material	Metal	Metal	Metal	Metal	Metal
	Resistance	—	—	—	—	—
	Bias	Grounded	Grounded	Grounded	Grounded	Grounded
Second Conveyance	Material	Insulant	Insulant	Insulant	Insulant	Insulant
	Resistance	—	—	—	—	—

TABLE 1-continued

		EC1	EC2	EC3	EC4	CC5
Belt Extension Roller 302	Bias	Grounded	Grounded	Grounded	Grounded	Grounded
Secondary Transfer Roller 304	Material	Foamed Polyurethane	Foamed Polyurethane	Foamed Polyurethane	Foamed Polyurethane	Polyurethane
	Resistance	6.5	6.5	6	5.5	7.5
	Bias	Grounded	Grounded	Grounded	Grounded	35 [μA]
Ultrasonic Vibration Generating Unit 400	Frequency	39.8 [kHz]	39.8 [kHz]	66.8 [kHz]	28.8 [kHz]	39.8 [kHz]
	Output	10 [W]	10 [W]	13 [W]	10 [W]	10 [W]
Embossed Paper Transferability		4.5	4.5	5	4.5	2.5
Two-color Toner Scattering		4	5	4.5	5	4
Uniform Transferability		4	5	5	5	4
Others						

In Table 1, "EC" represents Example Condition, and "CC" represents Conductive Condition.

TABLE 2

		CC1	CC2	CC3	CC4
Structure		FIG. 9	FIG. 7	FIG. 4	FIG. 4
Intermediate Transfer Belt 20	Material	Polyimide	Polyimide	Polyimide	Polyimide
	Thickness	80 [μm]	80 [μm]	80 [μm]	80 [μm]
	Surface Resistivity	11.5	11	11.8	8.5
	Volume Resistivity	9.6	8.8	9.2	7.8
Transfer Roller Opposed Roller 214	Material	Poly-urethane	Poly-urethane	Poly-urethane	Poly-urethane
	Resistance	7.5	7.5	7.5	7.5
	Bias	35 [μA]	35 [μA]	35 [μA]	35 [μA]
Secondary Transfer Roller 304	Material	NBR	NBR	NBR	NBR
	Resistance	5.5	5.5	5.5	5.5
	Bias	Grounded	Grounded	Grounded	Grounded
Vibration Generating Unit 400	Frequency	—	39.8 [kHz]	39.8 [kHz]	39.8 [kHz]
	Output	—	10 [W]	10 [W]	10 [W]
Embossed Paper		1	1.5	3	4
Two-color Toner Scattering		4	4	4	2
Uniform Transferability		5	5	5	5
Others				7.5 [kV] In-sufficient Power Source	

In Table 2, "CC" represents Comparative Condition.

In Table 1, the test results of Example Condition 1 were obtained by using a test apparatus having the configuration of Exemplary Embodiment 1, the test results of Example Conditions 2 to 4 were obtained by using a test apparatus having the configuration of Exemplary Embodiment 2, and the test results of Comparative Example 5 were obtained by using a test apparatus having Modified Exemplary Embodiment 2.

In Table 2, the test results of Comparative Condition 1 were obtained by using a test apparatus having a related-art configuration, the test results of Comparative Condition 1 were obtained by using a test apparatus having a configuration explained using FIG. 7, and Comparative Conditions 3 and 4 were obtained by using a test apparatus having a configuration of Modified Exemplary Embodiment 1.

The inventor of the present invention performed the measurement method of volume resistivity of the intermediate transfer belt **20** and the transfer sheet conveyance belt **300** according to the test of the present invention. The measurement conditions are as follows;

Resistance Measuring Instrument: HIRESTA-UP (manufactured by MITSUBISHI CHEMICAL CORPORATION);

Ring Probe: URS probe;

Object Supporting Member: REGI TABLE, with conductive rubber having thickness of 1 mm;

Measurement Voltage: 100V;

Measurement Time: 10 second point; and

Pressure Force: 2 kgf.

The inventor of the present invention also performed the measurement method of surface resistivity of the intermediate transfer belt **20** and the transfer sheet conveyance belt **300** according to the test of the present invention. The measurement conditions are as follows;

Resistance Measuring Instrument: HIRESTA-UP (manufactured by MITSUBISHI CHEMICAL CORPORATION);

Ring Probe: URS probe;

Object Supporting Member: REGI TABLE, insulated;

Measurement Voltage: 500V;

Measurement Time: 10 second point; and

Pressure Force: 2 kgf.

In this exemplary embodiment, volume resistivity and surface resistivity of the belt members shown in Tables 1 and 2 are described in common logarithm values;

Volume Resistivity: log (Ω·cm); and

Surface Resistivity: log (Ω/square).

FIG. **6** is a schematic view illustrating a measurement instrument for explaining a method of measuring the volume resistivity of a roller member used in the test.

The measurement instrument shown in FIG. **6** includes an opposing metal roller R**2**, a high voltage power source V, and an ammeter Va.

The opposing metal roller R**2** is a stainless roller having a diameter ϕ of 30 mm. A sample roller R**1** for measuring the volume resistivity is pressed at a force W of 50 gf/cm against the opposing metal roller R**2**. The opposing metal roller R**2** is fixed by a bearing. A given voltage is applied by the high voltage power source (610D, manufactured by TREK JAPAN CO., LTD.) to a place between the opposing metal roller R**2** and a shaft of the sample roller R**1** to measure the current flowing the opposing metal roller and the sample roller using the ammeter Va (6514, manufactured by KEITHLEY INSTRUMENTS INC.).

The high voltage power source and the ammeter Va are not limited to the above models.

It is possible to calculate the resistivity based on the given voltage and the measured current value manually. However, it is more preferable to automatically input, store, and process the measured data via a personal computer.

The resistivity was measured under an environment condition at a temperature of 22 degrees Celsius and at a relative humidity of 55% RH. When the environment condition is different, the value is corrected using absolute humidity.

If the sample roller R**1** includes an ion conductive roller, the resistance value of the ion conductive roller significantly depends on the temperature and humidity conditions, and therefore the measurement after adjustment of humidity is performed for 5 hours and more.

In this exemplary embodiment, the resistance value of the roller members shown in Tables 1 and 2 are also described in common logarithm values;

Roller Resistance: LogR ("R" is based on measured resistance.).

Next, a description is given of evaluation of images in the test.

In this test, the evaluation of images based on transferability to paper sheets having convex and concave portions to confirm improvement of transferability.

As for the transfer material, an A4-sized sheet of paper, SAZANAMI, manufactured by Ricoh, was used.

SAZANAMI is an embossed Japanese paper having convex and concave portions and has poor transferability in the concave portions, and more particularly, color on a two-color solid image such as an RGB image becomes uneven easily according to the concave portions. Generally, when a multi-layer toner image is formed by forming a two-color toner image such as an RGB image on the intermediate transfer belt **20**, the toner image on the upper layer thereof is transferred onto the transfer sheet S. However, it is difficult to transfer the toner image on the lower layer, and therefore the transferred toner image may be uneven because the toner image has some parts having a single-layer toner image and the other parts having two-layered or composite color toner image.

The transferability of toner image onto the SAZANAMI paper having the concave portions was evaluated and the evaluation was ranked.

The following shows the evaluation standard of transferability:

Rank 5 represents a highest rank indicating good image performance, that is, both the upper layer and lower layer of the toner image are transferred successfully and the toner image is reproduced in a same tone as the original document;

Rank 4 represents a threshold or border of acceptance and indicates that transfer of toner image on the upper layer is degraded and the color of toner on the lower layer is slightly observable;

Rank 3 indicates that the toner image on the upper layer is slightly transferred and the color of toner image on the lower layer is significantly observable;

Rank 2 indicates that the toner image on the upper layer is not transferred and only the color of toner image on the lower layer is transferred; and

Rank 1 indicates that the toner images on the upper and lower layer are not transferred and the background of the transfer sheet is observable on the concaved portions thereof.

Toner scattering on a transferred image was evaluated into ranks with RGB text images. The RGB text images were output and enlarged with a 20× magnification loupe to examine toner scattering around the texts. The following ranks describe evaluation standard of toner scattering of two-color text:

Rank 5 represents a highest rank indicating good image performance, that is, toner scattering is hardly found around the texts enlarged by the 20× magnification loupe;

Rank 4 represents a threshold or border of acceptance and indicates that only a small amount of toner scattering is found around the texts enlarged by the 20× magnification loupe but cannot be observed visually;

Rank 3 indicates that the color of toner scattering can slightly be observed around the texts visually;

Rank 2 indicates that the color of toner scattering can be observed around the texts visually; and

Rank 1 indicates that the range of toner scattering is wider and the color of toner scattering can be observed visually.

Uniform transfer ability represents transferability of a dot pattern image. If the transferability is poor, toner scattering occurs, which can result in high density of a toner image by visual check.

The following ranks describe evaluation standard of the uniform transfer ability:

Rank 5 represents a highest rank indicating good image performance, that is, a single color halftone solid image is transferred on a recording medium uniformly and smoothly;

Rank 4 indicates that a single color halftone solid image is transferred on a recording medium uniformly but slight density irregularity or a slight difference in grayscale values is observed;

Rank 3 indicates that a single color halftone solid image has density irregularity or a difference in grayscale values;

Rank 2 indicates that a halftone solid image has clear density irregularity or a clear difference in grayscale values; and

Rank 1 indicates that over the half or greater area of a halftone solid image is covered by deep gray density.

Next, a detailed description is given of units and components of the secondary transfer mechanism **30** of the image forming apparatus **500** used in the test.

In the image forming apparatus **500** used in the test, the surface of the intermediate transfer belt **20** moves at a speed of 285 millimeters per second [mm/sec]. The transfer area entrance roller **203** is a metallic roller that is grounded. The transfer area exit roller **204** is a roller having a metal shaft covered by an NBR material. The resistance is 6.8 in logarithmic expression obtained by applying 1,000 volts [V] for 10 seconds using the measurement method explained with FIG. **6**. The intermediate transfer belt **20** includes a polyimide resin having a thickness of 80 micrometers [μm], a surface resistivity of 10.5, and a volume resistivity of 8.8.

The transfer sheet conveyance belt **300** includes the same resistance as that of the intermediate transfer belt **20**. The first conveyance belt extension roller **301** that extends the transfer sheet conveyance belt **300** is a metallic roller that is grounded. The second conveyance belt extension roller **302** that extends the transfer sheet conveyance belt **300** is an insulating roller that is grounded.

The secondary transfer roller **304** that is disposed facing the secondary transfer bias applying member (e.g., the transfer area exit roller **204** and the voltage applying brush **205**) is a roller having a metallic roller covered by an elastic layer formed by urethane foam. The resistance of the secondary transfer roller **304** is 6.5 in logarithmic expression.

Further, the conductive brush fibers of the voltage applying brush **205** include carbon-containing acrylic fibers.

The level of vibration applied by the ultrasonic vibration generating unit **400** is at a frequency of 39.8 kilohertz [kHz] and an output of 10 watts [W]. For controlling the secondary transfer bias, the constant-current control was performed with 35 micro amps [μA] for the voltage applying brush **205** that is an upstream secondary transfer bias applying member and with 30 micro amps [μA] for the transfer area exit roller **204** that is a downstream secondary transfer bias applying member.

In the image forming apparatus **500** used in the test, the upper limit of capacity of the secondary transfer power source for generating the secondary transfer bias is set to 7 kilovolts [kV] according to easy occurrence of leakage to an adjacent member disposed in a vicinity of the secondary image transfer nip due to its duration.

In Example Conditions 1 through 4, a blue solid image was used for evaluation. The image to which the ultrasonic waves were applied was transferred uniformly to the concave portions. The upper secondary transfer power source V**1** applies a voltage of 3.2 kilovolts [kV] to the voltage applying brush **205** that is the upstream secondary transfer bias applying member, and the lower secondary transfer power source V**2** applies a voltage of 3.4 kilovolts [kV] to the transfer area exit roller **204** that is the downstream secondary transfer bias applying member. Accordingly, both voltages were below the upper limit voltage, 7 kilovolts [kV], of capacity of the power source.

[Comparative Example 1]

Next, a description is given of a schematic configuration of an image forming apparatus **500**A used as an apparatus for Comparative Example 1, which is used in Comparative Condition 2 in Table 2, referring to FIG. **7**.

As shown in FIG. **7**, the image forming apparatus **500**A includes a secondary transfer mechanism **30**A that includes an ultrasonic vibration generating unit **400**A. Elements or components of the image forming apparatus **500**A in FIG. **7** may be denoted by the same reference numerals as those of the image forming apparatus **500** according to an exemplary embodiment of the present invention and the descriptions thereof are omitted or summarized.

The ultrasonic vibration generating unit **400**A that includes the vibration imparting part **407** to contact at a position P on the intermediate transfer belt **20** to apply ultrasonic vibrations to the intermediate transfer belt **20** the inner surface of the intermediate transfer belt **20** between the transfer roller opposed roller **214** and the upstream extension roller **213** that is disposed upstream from the transfer roller opposed roller **214** in the direction A that is a direction of rotation of the intermediate transfer belt **20**.

In this configuration shown in FIG. **7**, the image forming apparatus **500**A further includes a transfer power source V**0** that applies a transfer bias voltage having the same polarity as toner of the toner image T to the transfer roller opposed roller **214**. Between the transfer roller opposed roller **214** and the secondary transfer roller **304** that is electrically grounded, a secondary image transfer nip N' is formed.

The inventor has found that this configuration of Comparative Example 1 does not improve the toner image transferability significantly compared to a configuration without the ultrasonic vibration generator. The detailed reason of this conclusion is described below.

In the configuration of the image forming apparatus **500**A as shown in FIG. **7**, the transfer roller opposed roller **214** serving as a transfer electric generating member and the secondary transfer roller **304** serving as a transfer electric generating member on the side of the transfer sheet S form the secondary image transfer nip N' by contacting to each other at the same position in the direction of rotation of the surface of the intermediate transfer belt **20**. Therefore, the secondary transfer electric field formed due to a difference in electric potential between the transfer roller opposed roller **214** and the secondary transfer roller **304** is generated only within a narrow nip width of the secondary image transfer nip N'. Therefore, in the configuration of FIG. **7**, even if ultrasonic vibrations are applied at a position where the vibration imparting part **407** contacts the intermediate transfer belt **20**, the secondary transfer electric field does not obtain a sufficient effect of the vibration, and the secondary image transfer nip N' where the secondary transfer electric field is formed is not affected by the vibrations sufficiently. Consequently, it is contemplated that the configuration of Comparative Example 1 shown in FIG. **7** does not improve the toner image transferability remarkably, compared to the configuration without employing the ultrasonic vibration generator.

In the configuration of Comparative Example 1 illustrated in FIG. **7**, the ultrasonic vibration generating unit **400**A may need to apply ultrasonic vibrations to the intermediate transfer belt **20** away from the secondary image transfer nip N'. Since the secondary transfer electric field is generated in the secondary image transfer nip N' formed between two rollers (e.g., the secondary transfer roller **304** and the transfer roller opposed roller **214**), even if the vibration imparting part **407** of the ultrasonic vibration generating unit **400**A contacts the position P that is away from the secondary image transfer nip N' to apply the ultrasonic vibrations to the intermediate transfer belt **20**, the ultrasonic vibration applied at the position P may not work effectively for improvement of the toner image transferability using the secondary transfer electric field. If the ultrasonic vibrations are applied to such a place on the intermediate transfer belt **20** where the secondary transfer electric field is hardly effective to the toner image transferability, the toner image T on the intermediate transfer belt **20** fixes to increase the adhesion force to the intermediate transfer belt **20**, thereby preventing enhancement of toner image transferability to the transfer sheet S.

By contrast, in the present invention, the transfer area exit roller **204** contacts the inner face of the intermediate transfer belt **20** in a direction of rotation of the intermediate transfer belt **20** at a position different from where the secondary transfer roller **304** contacts the intermediate transfer belt **20**. Therefore, even though the magnitude of the secondary transfer electric field may vary depending on the resistance/resistivity of the intermediate transfer belt **20** and the configuration of the secondary transfer member (for example, a belt-type member such as the transfer sheet conveyance belt **300** or a roller-type member such as the secondary transfer roller **304**), a secondary transfer electric field is formed over the entire area from where the transfer area exit roller **204** contacts the intermediate transfer belt **20** to where the secondary transfer roller **304** contacts the intermediate transfer belt **20**.

Further, the vibration imparting part **407** of the ultrasonic vibration generating unit **400** contacts the intermediate transfer belt **20** in the area formed between the transfer area exit roller **204** and the contact area of the secondary transfer roller **304** with respect to the intermediate transfer belt **20**. Therefore, ultrasonic vibrations can be applied to the intermediate transfer belt **20** within an area where the secondary transfer electric field is generated.

Further, in the present invention, the transfer area exit roller **204** contacts the inner face of the image conveyance belt extended surface portion **20***a* of the intermediate transfer belt **20**, and the secondary transfer roller **304** contacts the image conveyance belt extended surface portion **20***a* directly or via the intermediate transfer belt **20**.

Therefore, the vibration imparting part **407** of the ultrasonic vibration generating unit **400** that contacts the intermediate transfer belt **20** between the transfer area exit roller **204** and the secondary transfer roller **304** also contacts the image conveyance belt extended surface portion **20***a* of the intermediate transfer belt **20**.

Thus, with the configuration in which the vibration imparting part **407** of the ultrasonic vibration generating unit **400** contacts the image conveyance belt extended surface portion **20***a* of the intermediate transfer belt **20**, the present invention can apply ultrasonic vibrations to the position where the ultrasonic vibrations can be transmitted to the intermediate transfer belt **20** that serves as the toner image carrying member easily, compared to a related-art configuration in which the vibration is applied to a toner image carrying belt at a position where two rollers are disposed facing and pressed against each other.

[Comparative Example 2]

Next, a description is given of a configuration of Comparative Example 2 used in Comparative Condition 1 in Table 2, referring to FIGS. **8** and **9**.

FIG. **8** is a schematic configuration of an image forming apparatus **500**B as Comparative Example 2, and FIG. **9** is an enlarged view of a secondary transfer mechanism **30**B of the image forming apparatus **500**B.

Elements or components of the secondary transfer mechanism **30**B according to Comparative Embodiment 2 may be denoted by the same reference numerals as those of the secondary transfer mechanism **30**A according to Comparative Embodiment 1 and the descriptions thereof are omitted or summarized.

As shown in FIGS. **8** and **9**, the configuration of Comparative Embodiment 2 is similar to the configuration of Comparative Embodiment 1 shown in FIG. **7**. Except that the configuration of Comparative Embodiment 2 does not include the ultrasonic vibration generating unit **400**A and the secondary transfer roller **304** contacts the transfer roller opposed roller **214** via the intermediate transfer belt **20** but does not face the transfer roller opposed roller **214**, as shown in the transfer nip N' of FIG. **9**. That is, the secondary transfer roller **304** contacts the intermediate transfer belt **20** at a slightly upstream position from the position where the transfer roller opposed roller **214** contacts the opposite side of the intermediate transfer belt **20** in the direction of rotation of the surface of the intermediate transfer belt **20**. By displacing the contact position of the secondary transfer roller **304** to the intermediate transfer belt **20** from the contact position of the transfer roller opposed roller **214** to the intermediate transfer belt **20**, a pressing force to press the transfer sheet S against the surface of the intermediate transfer belt **20** is exerted, thereby increasing adhesion between the intermediate transfer belt **20** and the transfer sheet S.

However, toner particles become cohesive due to a nip pressure between the transfer roller opposed roller **214** and the secondary transfer roller **304**, which can result in defects in transfer such as hollow defects of texts and insufficient transfer with respect to less smooth papers and embossed papers.

Even if the secondary transfer roller **304** employs either a secondary transfer system in which an image is transferred onto a transfer sheet directly or a transfer conveyance belt system in which an image is transferred onto a transfer sheet via a transfer conveyance belt, it is preferable that a secondary transfer bias applying member and the transfer sheet do not directly contact when a secondary transfer bias is applied.

Further, if the humidity of a transfer sheet is controlled and the resistance is decreased, the electric current flows into registration rollers and metallic guide members to cause void. Therefore, the secondary transfer bias is preferably applied from the back side of an intermediate transfer belt. However, this application method is not to be limited.

The configurations of Exemplary Embodiments 1 and 2 employ the conductive voltage applying brush **205** as one of the secondary transfer bias applying members, and the vibration imparting part **407** is disposed on the intermediate transfer belt **20** between the voltage applying brush **205** and the secondary transfer roller **304**. If the vibration imparting part **407** is disposed between the contact position of the transfer area exit roller **204** and the contact position of the secondary transfer roller **304**, the vibration imparting part **407** may need to be located at the left side of the left edge of the transfer area exit roller **204** in FIG. **2** and the secondary transfer roller **304** may need to be located on the left side of the transfer area exit roller **204**. Under this condition, the contact position of the transfer area exit roller **204** and the contact position of the secondary transfer roller **304** may need to be separated. The more the distance between the secondary transfer bias applying member (e.g., the transfer area exit roller **204**) and the transfer electric generating member on the transfer sheet side (e.g., the secondary transfer roller **304**) disposed sandwiching the vibration imparting part **407** therebetween increases, the greater the resistance value when the electric current flows through the intermediate transfer belt **20** becomes, and therefore the difference in electric potential may need to be increased and the resistivity of the belt may need to be decreased.

The configurations of Exemplary Embodiments 1 and 2 provide the vibration imparting part **407** between the voltage applying brush **205** and the secondary transfer roller **304**, and therefore the contact position of the voltage applying brush **205** to the intermediate transfer belt **20** and the contact position of the vibration imparting part **407** to the intermediate transfer belt **20** can be arranged closer. Further, the distance between the contact position of the voltage applying brush **205** to the intermediate transfer belt **20** and the contact position of the secondary transfer roller **304** to the intermediate transfer belt **20** can be smaller. Thereby, the distance for electric current to flow between the voltage applying brush **205** and the secondary transfer roller **304** with respect to the intermediate transfer belt **20** can be reduced and the bad influence of resistance of the intermediate transfer belt **20** can be suppressed.

The configurations of Exemplary Embodiments 1 and 2 provide the vibration imparting part **407** between the voltage applying brush **205** and the secondary transfer roller **304**, and therefore the contact position of the voltage applying brush **205** to the intermediate transfer belt **20** and the contact position of the vibration imparting part **407** to the intermediate transfer belt **20** can be arranged closer. Further, the distance between the contact position of the voltage applying brush **205** to the intermediate transfer belt **20** and the contact position of the secondary transfer roller **304** to the intermediate transfer belt **20** can be smaller. Thereby, the distance for electric current to flow between the voltage applying brush **205** and the secondary transfer roller **304** on the intermediate transfer belt **20** can be reduced and the bad influence of resistance of the intermediate transfer belt **20** can be suppressed.

Further, the transfer area exit roller **204** is provides as a downstream secondary transfer bias applying member. However, it is not necessary to provide the vibration imparting part **407** between the contact position of the transfer area exit roller **204** and the contact position of the secondary transfer roller **304**, thereby reducing the distance between these contact positions.

In the configurations of Example Conditions 1 through 4, which correspond to the configurations illustrated in FIGS. **2** and **3**, the distance between the contact position of the voltage applying brush **205** serving as a transfer electric generating member on the photoconductor side and the contact position of the secondary transfer roller **304** serving as a transfer electric generating member on the transfer sheet side on the intermediate transfer belt **20** was 5 millimeters [mm]. Also, the distance between the contact position of the transfer area exit roller **204** serving as a transfer electric generating member on the photoconductor side and the contact position of the secondary transfer roller **304** on the intermediate transfer belt **20** was 15 millimeters [mm].

By contrast, in the configuration of Comparative Conditions 3 and 4, which correspond to the configuration illustrated in FIG. **4**, the distance between the contact position of the transfer roller opposed roller **214** and the contact position of the secondary transfer roller **304** on the intermediate transfer belt **20** was 20 millimeters [mm]. Further, in the configuration of Comparative Condition 5, which correspond to the configuration illustrated in FIG. **5**, the distance between the contact position of the transfer area exit roller **204** and the contact position of the secondary transfer roller **304** on the intermediate transfer belt **20** was 20 millimeters [mm].

As described above, the distance from the position of the transfer roller opposed roller **214** to contact the intermediate transfer belt **20** to the position of the secondary transfer roller **304** to contact the intermediate transfer belt **20** in the configuration shown in FIG. **4** is longer than the distance from the position of the voltage applying brush **205** to contact the intermediate transfer belt **20** to the position of secondary transfer roller **304** to contact the intermediate transfer belt **20** in the configurations shown in FIGS. **2** and **3**. Therefore, as shown in Comparative Condition 3, if the secondary transfer bias of 35 micro amps [μA] having the constant current control is applied without setting the setting of the surface resistivity of the intermediate transfer belt **20** to a low value, the transferability has enhanced and no image characteristics are adversely affected. However, the voltage of 7.5 kilovolts [kV] of the secondary transfer bias is required, which exceeds the upper limit of the power source capacity, 7 kilovolts [kV], and therefore it is difficult to employ the configuration for practical use.

In addition, to maintain the voltage of the secondary transfer bias at 7.0 kilovolts [kV] or below, as shown in Comparative Condition 4, the surface resistivity of the intermediate transfer belt **20** is decreased, thereby enhancing the transferability but degrading toner scattering of two-color texts among other image characteristics.

Further, the distance between the contact position of the transfer area exit roller **204** to the intermediate transfer belt **20** and the contact position of the secondary transfer roller **304** to the intermediate transfer belt **20** is longer in the configuration illustrated in FIG. **5** than in the configurations illustrated in FIGS. **2** and **3**. If electric current is difficult to flow smoothly to the intermediate transfer belt **20**, the voltage of the secondary transfer bias can exceed the limit of power source capacity or the resistivity of the intermediate transfer belt **20** can be decreased. To prevent these disadvantages, the surface resistivity of the transfer sheet conveyance belt **300** is set low. Thus, when only the surface resistivity of the transfer sheet conveyance belt **300** without decreasing the surface resistivity of the intermediate transfer belt **20**, electric current flows over the surface of the transfer sheet conveyance belt **300** to the position opposite the transfer area exit roller **204**, as indicated by arrow E in FIG. **5** and the electric current flows to the transfer area exit roller **204** via the transfer sheet S, the toner layer T, and the intermediate transfer belt **20**. Therefore, the magnitude of the secondary transfer electric field increases at the opposite position of the transfer sheet conveyance belt **300** and the transfer area exit roller **204** and the magnitude of the secondary transfer electric field decreases at the position where the vibration imparting part **407** contacts the intermediate transfer belt **20**. Therefore, the configuration of Comparative Condition 5 is less effective in enhancing transferability by application of ultrasonic vibrations, compared to the configurations of Exemplary Embodiments 1 and 2.

In an exemplary embodiment, one of two secondary transfer bias applying members is a voltage applying brush and the other is a roller-shaped member. Alternatively, both of the two secondary transfer bias applying members can be a voltage applying brush. However, if a secondary transfer bias applying member different from the extension roller at the trailing edge of the image conveyance belt extended surface portion is provided, a voltage applying brush may need to be disposed upstream by half or more of the radius of the extension roller at the trailing edge from the trailing edge of the extended surface portion, and the contact position of the transfer sheet side transfer electric generating member may need to be disposed further upstream from the voltage applying brush, thereby increasing the size of the apparatus.

In the configuration in an exemplary embodiment of the present invention, a toner image carrying belt corresponds to the intermediate transfer belt **20** and an image receiving member to be transferred corresponds to the transfer sheet S. However, the combination of a toner image carrying belt that forms a transfer part to apply ultrasonic vibrations to the transfer nip is not limited thereto. For example, a configuration to transfer an image from a belt-shaped image carrier to an image forming member or to a transfer sheet is applicable to the present invention.

As described above, the image forming apparatus **500** according to an exemplary embodiment of the present invention includes the intermediate transfer belt **20**, multiple extension rollers **201**, **202**, **203**, **204**, **206**, and **207**, the transfer sheet conveyance belt **300**, and the ultrasonic vibration generating unit **400**.

The intermediate transfer belt **20**, which serves as a toner image carrying belt or an endless transfer belt, is wound around the multiple extension rollers **201**, **202**, **203**, **204**, **206**, and **207** and rotates in an endless manner while carrying a toner image on a surface thereof.

The transfer sheet conveyance belt **300**, which serves as a secondary transfer unit and an endless transfer belt, is disposed facing the intermediate transfer belt **20**. The surface of the transfer sheet conveyance belt **300** is rotated with the intermediate transfer belt **20** in an endless manner in a direction of rotation of the intermediate transfer belt **20**. The transfer sheet conveyance belt **300** forms the secondary image transfer nip for transferring a toner image on the intermediate transfer belt **20** onto the surface of the transfer sheet S serving as a recording medium at an opposed portion of the intermediate transfer belt **20**.

The ultrasonic vibration generating unit **400** serves as an ultrasonic vibration generator is disposed inboard of the intermediate transfer belt **20**, and includes the vibration imparting part **407** that contacts the inner face of the intermediate transfer belt **20**. The ultrasonic vibration generating unit **400** imparts ultrasonic vibrations from the vibration imparting part **407** to the intermediate transfer belt **20**.

With this configuration, the image forming apparatus **500** forms the secondary transfer electric field in the secondary image transfer nip by the action of the difference in electric potential between the transfer area exit roller **204** and the voltage applying brush **205**, both of which are photoconductor transfer electric generating members, disposed on the inner face side of the intermediate transfer belt **20** and the secondary transfer roller **304** that is also a secondary transfer member and a transfer electric generating member disposed on the inner face side of the transfer sheet conveyance belt **300**.

The secondary image transfer nip formed in the image forming apparatus **500** is formed between one of the extended surface portions (e.g., the image conveyance belt extended surface portion **20***a*) of the intermediate transfer belt **20** and the contact position of the surface of the transfer sheet conveyance belt **300**.

Both the transfer area exit roller **204** and the voltage applying brush **205** contact the inner face side of the image conveyance belt extended surface portion **20***a* of the intermediate transfer belt **20**. The image conveyance belt extended surface portion **20***a* serves as the transfer nip extended surface portion on the photoconductor side of the intermediate transfer belt **20**. In the secondary image transfer nip, the secondary transfer roller **304** contacts the image conveyance belt extended surface portion **20***a* via the transfer sheet conveyance belt **300** serving as the endless transfer belt and the secondary transfer unit. The contact position of the secondary transfer roller **304** to the intermediate transfer belt **20** is displaced from the contact positions of the transfer area exit roller **204** and the voltage applying brush **205** to the intermediate transfer belt **20** in the direction of rotation of the intermediate transfer belt **20**. The vibration imparting part **407** of the ultrasonic vibration generating unit **400** is disposed between the contact position of the voltage applying brush **205**, which serves as one of the two photoconductor transfer electric generating members, to the intermediate transfer belt **20** and the contact position of the secondary transfer roller **304** to the intermediate transfer belt **20**.

With this configuration, the image forming apparatus **500** can impart the ultrasonic vibrations to the intermediate transfer belt **20**, within the area on the intermediate transfer belt **20** where the secondary transfer electric field is formed by the action of the difference in electric potential between the voltage applying brush **205** and the secondary transfer roller **304**.

Further, the vibration imparting part **407** contacts the intermediate transfer belt **20** at a different position from the intermediate transfer belt **20** is extended by the extension rollers, the ultrasonic vibrations can be transmitted easily, compared to the configuration in which ultrasonic vibrations is imparted to the intermediate transfer belt **20** where the rollers disposed facing each other and contact at the same position on the intermediate transfer belt **20**.

Accordingly, the image forming apparatus **500** having this configuration can transmit the ultrasonic vibrations to the intermediate transfer belt **20** easily. In addition, the vibration imparting part **407** of the ultrasonic vibration generating unit **400** contacts in the area where the secondary transfer electric field is generated on the intermediate transfer belt **20**, thereby enhancing the transferability assuredly by imparting the ultrasonic vibrations.

Further, in the image forming apparatus **500** according to an exemplary embodiment of the present invention, the secondary transfer member or the transfer sheet conveyance member is the transfer sheet conveyance belt **300** that is wound around the multiple extension rollers. The secondary image transfer nip is formed between one of the extended surface portions of the transfer sheet conveyance belt **300** as a belt-shaped secondary transfer member and the image conveyance belt extended surface portion **20***a*, and the secondary transfer roller **304** serving as the transfer sheet side transfer electric generating member contacts the inner face side of the transfer sheet conveyance belt **300** in the secondary image transfer nip. By forming the secondary image transfer nip where the belt members contact each other, the nip width of the secondary image transfer nip can increase assuredly.

Further, in the image forming apparatus **500** according to an exemplary embodiment of the present invention, the first conveyance belt extension roller **301** and the second conveyance belt extension roller **302**, both of which serve as extension rollers to extend the transfer sheet conveyance belt **300** are rotated with the rotation of the transfer sheet conveyance belt **300**. Specifically, in the configuration of Exemplary Embodiment 2, the first conveyance belt extension roller **301** is electrically grounded and the inlet roller power source V**3** applies a bias voltage having a polarity opposite that of the toner to the transfer area entrance roller **203**. Thus, an electric field is formed in a vicinity of the entrance of the secondary image transfer nip to attract the toner image T carried on the surface of the intermediate transfer belt **20** and the transfer sheet conveyance belt **300** to the intermediate transfer belt **20**. If the electric field to attract the toner to the transfer sheet conveyance belt **300** is formed between the intermediate transfer belt **20** and the transfer sheet conveyance belt **300** at the entrance of the secondary image transfer nip, it is likely that toner scattering due to a transfer image operation across the gap between the intermediate transfer belt **20** and the transfer sheet conveyance belt **300** occurs to scatter toner on the transfer member, etc.

Further, since no electrostatic attraction force exists between a position upstream from the secondary transfer electric field formed by the secondary transfer bias on the intermediate transfer belt **20** and the transfer sheet conveyance belt **300**, the adhesion between the intermediate transfer belt **20** and the transfer sheet conveyance belt **300** is low. Therefore, if the transfer sheet S is conveyed to a position intermediate between these belts having a low adhesion therebetween, the transfer sheet S can be displaced, which is susceptible to slur of the reproduced toner image

Further, in the configuration in which one of the extension rollers around which the transfer sheet conveyance belt **300** is extended and is a driven roller and the intermediate transfer belt **20** and the transfer sheet conveyance belt **300** are rotated by respective drive rollers disposed inside these belts, the difference in rotation speed of the surfaces between two belts in the secondary image transfer nip cannot be eliminated completely. If the transfer sheet conveyance belt **300** closely contacts the intermediate transfer belt **20** electrostatically while there is a difference in rotation speed of the surfaces of the two belt members, slur of reproduced toner images can be caused easily due to the difference in rotation speed between the surfaces of these belt members.

In the image forming apparatus **500** according to Exemplary Embodiment 2 of the present invention, a bias voltage having a polarity opposite the toner image T on the surface of the intermediate transfer belt **20** is applied to the transfer area entrance roller **203** that forms the entrance part of the secondary image transfer nip formed between the intermediate transfer belt **20** and the transfer sheet conveyance belt **300**. This action can prevent toner scattering in the gap upstream from the entrance part of the secondary image transfer nip.

Further, the bias voltage is applied to the transfer area entrance roller **203**, the transfer sheet conveyance belt **300** is electrostatically attracted at the entrance part of the secondary image transfer nip to the intermediate transfer belt **20** to closely contact the transfer sheet conveyance belt **300** to the intermediate transfer belt **20**. However, the transfer sheet conveyance belt **300** that does not include a drive roller is rotated with the intermediate transfer belt **20** by adhering closely thereto. This action can prevent a difference in rotation speed of each surface between the transfer sheet conveyance belt **300** and the intermediate transfer belt **20**. Accordingly, slur of the transfer sheet S due to the difference in rotation speed of each surface of the transfer sheet conveyance belt **300** and the intermediate transfer belt **20** can be prevented, thereby further preventing the slur of reproduced toner images.

Thus, the image forming apparatus **500** according to Exemplary Embodiment 2 of the present invention employs the transfer sheet conveyance belt **300** that is rotated with the intermediate transfer belt **20**, and therefore can prevent occurrence of lateral or transversal band-shaped density nonuniformity such as banding caused by a difference in speed between the intermediate transfer belt **20** and the transfer sheet conveyance belt **300** or in thickness of paper sheets.

Further, a bias voltage having a polarity opposite the toner image T on the surface of the intermediate transfer belt **20** is applied to the transfer area entrance roller **203** that forms the entrance part of the secondary image transfer nip. This action can prevent toner scattering in the gap upstream from the entrance part of the secondary image transfer nip.

Further, the ultrasonic vibrations are applied by increasing the adhesion force between the intermediate transfer belt **20** and the transfer sheet S, so that the toner scattering caused by the gap across the intermediate transfer belt **20** and the transfer sheet S can be prevented.

Further, in the image forming apparatus **500** according to Exemplary Embodiment 2 of the present invention, the inlet roller power source V**3** applies a bias voltage to the transfer area entrance roller **203** that serves as an extension roller extending the intermediate transfer belt **20** at the upstream end part of the image conveyance belt extended surface portion and the first conveyance belt extension roller **301** is electrically grounded. Under this configuration, a difference in electric potential between the transfer area entrance roller **203** and the first conveyance belt extension roller **301** attracts the toner image T carried on the intermediate transfer belt **20** and the transfer sheet conveyance belt **300** to the intermediate transfer belt **20**.

Thus, one of the transfer area entrance roller **203** and the first conveyance belt extension roller **301** is applied with the bias voltage and the other is located in a vicinity of the entrance of the secondary image transfer nip to attract the toner to the intermediate transfer belt **20**. Accordingly, to prevent toner scattering near the entrance of the secondary image transfer nip and slur of the transfer sheet S in the secondary image transfer nip, an effective electric field can be provided without additionally providing a particular bias applying member.

Further, the image forming apparatus **500** according to an exemplary embodiment of the present invention includes two photoconductor transfer electric generating members, which are the voltage applying brush **205** and the transfer area exit roller **204**. In this configuration, the vibration imparting part **407** of the ultrasonic vibration generating unit **400** contacts the intermediate transfer belt **20** between the position where the voltage applying brush **205** contacts the intermediate transfer belt **20** and the position where the transfer area exit roller **204** contacts the intermediate transfer belt **20**. Thus, this configuration includes at least two photoconductor transfer electric generating members, and the vibration imparting part **407** contacts the intermediate transfer belt **20** therebetween. By so doing, a wider area for forming the secondary transfer electric field can be obtained and a longer period of time for the image transfer operation can be assured. Further, the application of the ultrasonic vibrations to the intermediate transfer belt **20** in the area where the transfer electric field is formed can reduce the adhesion force of toner to the intermediate transfer belt **20**, thereby achieving good transferability for a transfer sheet having convex and concave portions such as an embossed paper.

Further, the vibration imparting part **407** of the ultrasonic vibration generating unit **400**A contacts the intermediate transfer belt **20** between the position where a roller-type photoconductor transfer electric generating member contacts the intermediate transfer belt **20** and the position where the secondary transfer roller **304** contacts the intermediate transfer belt **20** in the related-art configuration. In this configuration, however, the contact position of the roller-type photoconductor transfer electric generating member is separated from the contact position of the vibration imparting part **407** of the ultrasonic vibration generating unit **400**A. And, the contact position of the roller-type photoconductor transfer electric generating member is also separated from the contact position of the secondary transfer roller **304**. If the photoconductor transfer electric generating member contacts the intermediate transfer belt **20** at a position apart from the secondary transfer roller **304**, the flow of the secondary transfer electric current may be impaired, and the bias voltage may be increased to flow the electric current. An increase in the bias voltage can cause an excess of the upper limit of the power source capacity and electric discharging between the adjacent members.

By contrast, in the image forming apparatus **500** according to an exemplary embodiment of the present invention, the vibration imparting part **407** of the ultrasonic vibration generating unit **400** contacts the intermediate transfer belt **20** at the position intermediate between where the voltage applying brush **205** that is a brush-type photoconductor transfer electric generating member contacts the intermediate transfer belt **20** and where the secondary transfer roller **304** contacts the intermediate transfer belt **20**. With this configuration, the vibration imparting part **407** can be disposed adjacent the contact position of the voltage applying brush **205**. Therefore, this configuration can arrange the contact position of the photoconductor transfer electric generating member and the contact position of the secondary transfer roller **304** adjacent to each other. This can prevent problems due to a less amount of flow of the secondary transfer electric current caused by the resistance of the intermediate transfer belt **20**.

Further, in the image forming apparatus **500** according to an exemplary embodiment of the present invention, the secondary transfer roller **304** serving as the second transfer electric field generator contacts the intermediate transfer belt **20** between the voltage applying brush **205** and the transfer area exit roller **204**, both of which are the two adjacent first transfer electric field generators, with the transfer sheet conveyance belt **300** interposed between the secondary transfer roller **304** and the voltage applying brush **205** and the transfer area exit roller **204**.

The secondary transfer bias having a same polarity as the toner is applied to the voltage applying brush **205** and the transfer area exit roller **204** and the secondary transfer roller **304** that is grounded is disposed between the voltage applying brush **205** and the transfer area exit roller **204**. By so doing, the electric current flows to the grounded secondary transfer roller **304** from both the upstream and downstream sides in the direction of rotation of the intermediate transfer belt **20**, and the area through which the electric current flows forms the secondary transfer electric field. By forming the secondary transfer electric field on the upstream and downstream sides from the secondary transfer roller **304**, the distance of each flow of the electric current can be increased without the distance of the electric current flowing through the intermediate transfer belt **20**. This can prevent problems due to a less amount of flow of the secondary transfer electric current caused by the resistance of the intermediate transfer belt **20** and can obtain a wide area for forming the secondary transfer electric field.

Then, the vibration imparting part **407** applies the ultrasonic vibrations to the intermediate transfer belt **20**, which is the wide area for forming the secondary transfer electric field, so as to obtain a wider area for the transfer electric field to assure a longer period of time for the image transfer operation. Further, the application of the ultrasonic vibrations to the intermediate transfer belt **20** in the area where the transfer electric field is formed can reduce the adhesion force of toner to the intermediate transfer belt **20**, thereby achieving good transferability for a transfer sheet having convex and concave portions such as an embossed paper.

Further, by reducing the distance of flow of the electric current through the intermediate transfer belt **20**, the high surface resistivity of the intermediate transfer belt **20** can be set, which can prevent toner scattering in the primary image transfer operation.

Further, at least one of the surface resistivity of the outer surface and the surface resistivity of the inner surface of the intermediate transfer belt **20** used in the image forming apparatus **500** falls within a range of from 1×10^9 [Ω/square] to 1×10^{12} [Ω/square].

Conventionally, when an image forming apparatus includes one photoconductor transfer electric generating member, i.e., includes the transfer roller opposed roller **214** only, the surface resistivity of the intermediate transfer belt **20** was preferably 1×10^{10} [Ω/square] or smaller, more preferably 1×10^9 [Ω/square] or smaller. If the intermediate transfer belt **20** having the surface resistivity of this range is used in a tandem-type image forming apparatus, electric current flows between primary transfer bias applying members, causing current interference to result in improper toner image transfer.

By contrast, the image forming apparatus **500** according to an exemplary embodiment of the present invention includes multiple photoconductor transfer electric generating members to form a wider transfer nip for the secondary image transfer operation and employs a belt member having a relatively high surface resistivity (e.g., the intermediate transfer belt **20**), and therefore can prevent toner scattering in the primary image transfer operation and provide toner image having good transfer efficiency.

Further, the secondary image transfer nip N formed in the secondary transfer part (e.g., the secondary transfer mechanism **30**, **30'**, **30**M, or **30**M') of the image forming apparatus **500** serves as a recording medium transfer nip to transfer the toner image T held on the intermediate transfer belt **20** onto the transfer sheet S serving as a recording medium, thereby providing good toner image transferability to the transfer sheet S.

The above-described exemplary embodiments are illustrative, and numerous additional modifications and variations are possible in light of the above teachings. For example, elements and/or features of different illustrative and exemplary embodiments herein may be combined with each other and/or substituted for each other within the scope of this disclosure. It is therefore to be understood that, the disclosure of this patent specification may be practiced otherwise than as specifically described herein.

Obviously, numerous modifications and variations of the present invention are possible in light of the above teachings. It is therefore to be understood that, the invention may be practiced otherwise than as specifically described herein.

What is claimed is:

1. An image forming apparatus, comprising:

a first endless transfer belt to carry a toner image thereon after a primary image transfer operation onto a surface of the first endless transfer belt during rotation of the first endless transfer belt;

first extension members around which the first endless transfer belt is extended;

at least one first transfer electric field generator disposed inside of a loop of the first endless transfer belt;

a secondary transfer unit disposed outside of the loop of and at least partially facing the first endless transfer belt to transfer the toner image onto a transfer medium conveyed by the secondary transfer unit; and

an ultrasonic vibration generator to generate ultrasonic vibrations, the ultrasonic vibration generator being disposed inside the loop of the first endless transfer belt and including a vibration imparting part from which the ultrasonic vibrations are applied to an inner face of the first endless transfer belt,

wherein the secondary transfer unit is disposed facing and in contact with a first surface portion of the first endless transfer belt to form a transfer nip therebetween, through which the transfer medium is conveyed when the toner image is transferred onto the transfer medium in a secondary image transfer operation, the secondary transfer unit including a secondary transfer roller that faces and contacts an inner face of a second endless transfer belt in the transfer nip to contact the first endless transfer belt via the second endless transfer belt,

wherein the transfer nip has a transfer electric field due to a difference in electric potential between the first endless transfer belt and the secondary transfer unit,

wherein the first transfer electric field generator contacts the inner face of the first surface portion of the first endless transfer belt in the transfer nip and the secondary transfer unit presses against the first endless transfer belt at a position along the first endless transfer belt opposite the first transfer electric field generator with the first endless transfer belt interposed therebetween,

wherein the vibration imparting part of the ultrasonic vibration generator contacts the first endless transfer belt at an intermediate position between a contact point of the first transfer electric field generator with the first endless transfer belt and a contact point of the secondary transfer unit with the first endless transfer belt in a direction of rotation of the first endless transfer belt, and

wherein the vibration imparting part of the ultrasonic vibration generator contacts the first endless transfer belt at a position upstream from the contact point of the secondary transfer unit with the first endless transfer belt in a direction of rotation of the first endless transfer belt.

2. The image forming apparatus according to claim **1**, wherein the at least one first transfer electric field generator includes a plurality of first transfer electric field generators,

wherein at least one of the first extension members around which the first endless transfer belt is extended constitutes a first field generator of the plurality of first transfer electric field generators, and

wherein the secondary transfer roller is disposed at an intermediate position between the first field generator of the plurality of first transfer electric field generators and a second field generator of the plurality of first electric field generators in a direction of rotation of the first endless transfer belt.

3. The image forming apparatus according to claim 1, wherein the at least one first transfer electric field generator includes a plurality of first transfer electric field generators, and

wherein the vibration imparting part of the ultrasonic vibration generator is disposed between one of the plurality of first transfer electric field generators and the secondary transfer roller.

4. The image forming apparatus according to claim 1, wherein the at least one first transfer electric field generator includes a plurality of first transfer electric field generators, and

wherein the vibration imparting part of the ultrasonic vibration generator contacts the first endless transfer belt between two adjacent first transfer electric field generators of the plurality of first transfer electric field generators that contact the first endless transfer belt.

5. The image forming apparatus according to claim 4, wherein the secondary transfer unit includes a second transfer electric field generator that contacts the first endless transfer belt between at least two adjacent first transfer electric field generators of the plurality of first transfer electric field generators.

6. The image forming apparatus according to claim 5, wherein the vibration imparting part of the ultrasonic vibration generator contacts the first endless transfer belt at a position upstream of a contact point of the second transfer electric field generator with the first endless transfer belt in the direction of rotation of the first endless transfer belt.

7. The image forming apparatus according to claim 1, wherein at least one of a surface resistivity of an outer surface and a surface resistivity of an inner surface of the first endless transfer belt falls within a range of from 1×10^9 [Ω/square] to 1×10^{12} [Ω/square].

8. The image forming apparatus according to claim 1, wherein the transfer nip transfers the toner image held on the first endless transfer belt onto a recording medium.

9. An image forming apparatus, comprising:

a first endless transfer belt that carries a toner image thereon after a primary image transfer operation onto a surface of the first endless transfer belt during rotation of the first endless transfer belt;

first extension members around which the first endless transfer belt is extended;

a plurality of first transfer electric field generators disposed inside of a loop of the first endless transfer belt;

a secondary transfer unit disposed outside of the loop of and at least partially facing the first endless transfer belt to transfer the toner image onto a transfer medium conveyed by the secondary transfer unit; and

an ultrasonic vibration generator to generate ultrasonic vibrations, the ultrasonic vibration generator being disposed inside the loop of the first endless transfer belt and including a vibration imparting part from which the ultrasonic vibrations are applied to an inner face of the first endless transfer belt,

wherein the secondary transfer unit is disposed facing and in contact with a first surface portion of the first endless transfer belt to form a transfer nip therebetween, through which the transfer medium is conveyed when the toner image is transferred onto the transfer medium in a secondary image transfer operation,

wherein the secondary transfer unit includes a secondary transfer roller disposed facing and in contact with an inner face of a second endless transfer belt in the transfer nip to contact the first endless transfer belt via the second endless transfer belt,

wherein the transfer nip has a transfer electric field due to a difference in electric potential between the first endless transfer belt and the secondary transfer unit,

wherein the plurality of first transfer electric field generators contact the inner face of the first surface portion of the first endless transfer belt in the transfer nip and the secondary transfer unit presses against the first endless transfer belt opposite the plurality of first transfer electric field generators with the first endless transfer belt interposed therebetween,

wherein the vibration imparting part of the ultrasonic vibration generator contacts the first endless transfer belt at a position between two adjacent first transfer electric field generators of the plurality of first transfer electric field generators that contact the first endless transfer belt, and

wherein the vibration imparting part of the ultrasonic vibration generator contacts the first endless transfer belt at a position upstream of where the secondary transfer roller contacts the first endless transfer belt in a direction of rotation of the first endless transfer belt.

10. The image forming apparatus according to claim 9, wherein at least one of the first extension members around which the first endless transfer belt is extended constitutes a first field generator of the plurality of first transfer electric field generators, and

wherein the secondary transfer roller is disposed at an intermediate position between the first field generator of the plurality of first transfer electric field generators and a second field generator of the plurality of first transfer electric field generators in the direction of rotation of the first endless transfer belt.

11. The image forming apparatus according to claim 9, wherein the vibration imparting part of the ultrasonic vibration generator is disposed between one of the plurality of first transfer electric field generators and the secondary transfer roller.

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UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 8,682,236 B2
APPLICATION NO. : 12/725033
DATED : March 25, 2014
INVENTOR(S) : Yuuji Sawai

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

On the title page, Item (75), the Inventor's Last Name is incorrect. Item (75) should read:

--(75) Inventor: **Yuuji Sawai**, Yokohama (JP)--

Signed and Sealed this
Twenty-fourth Day of June, 2014

Michelle K. Lee

Michelle K. Lee
Deputy Director of the United States Patent and Trademark Office

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 8,682,236 B2
APPLICATION NO. : 12/725033
DATED : March 25, 2014
INVENTOR(S) : Yuuji Sawai

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

On the title page, Item (12), delete “Sawaj” and insert --Sawai--

On the title page, Item (75), the Inventor’s Last Name is incorrect. Item (75) should read:

--(75) Inventor: **Yuuji Sawai**, Yokohama (JP)--

This certificate supersedes the Certificate of Correction issued June 24, 2014.

Signed and Sealed this
Fifth Day of August, 2014

Michelle K. Lee

Michelle K. Lee
Deputy Director of the United States Patent and Trademark Office